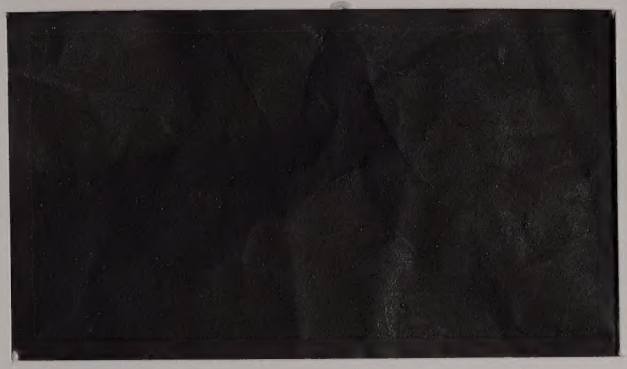
BARBER COLMAN



INSTRUCTION MANUAL

357A
76F1958

UNIT 3PPC-3/14-230/115X 12

SN 1030

TuK. 35747

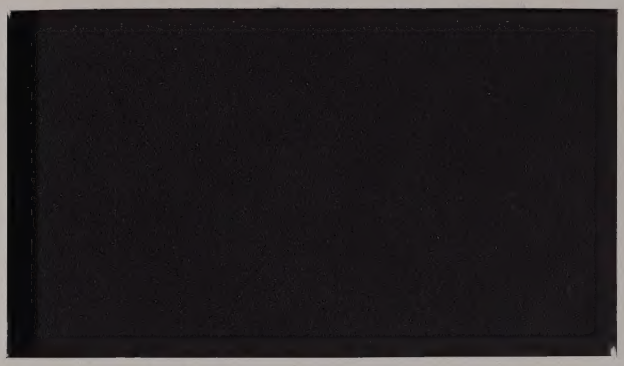
STEPLESS CONTROLS
WALTHAM, MASS.

POWER CONTROL
MOD. MC-3

PROTEKTALL
MOD. O-H1

SPEED CONTROL
MOD. SC-2

BARBER-COLMAN COMPANY
Industrial Instruments Div. • Rockford, Ill., U.S.A.



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IN 2-3

MODEL 357A

DIGISET

NULL BALANCE CONTROLLER

INTRODUCTION

This instruction manual is designed to help you secure maximum benefits from your new Model 357A Digiset. It should be given to persons responsible for installation, operation and maintenance of this instrument.

Your Barber-Colman factory trained field engineer is always available for further help in the solution of your control problems. Offices are located in all principal cities.

BARBER-COLMAN COMPANY
Industrial Instruments Division

Litho in U.S.A.

June 1967

MODEL 357A INSTRUCTION MANUAL

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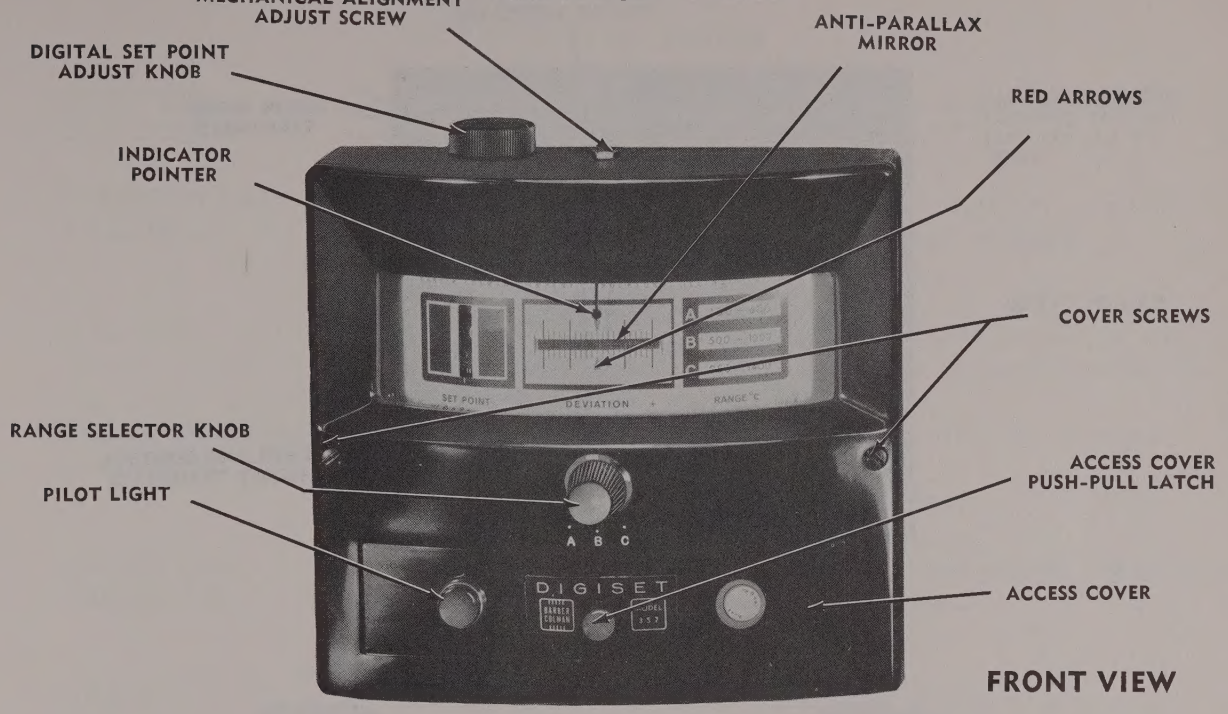
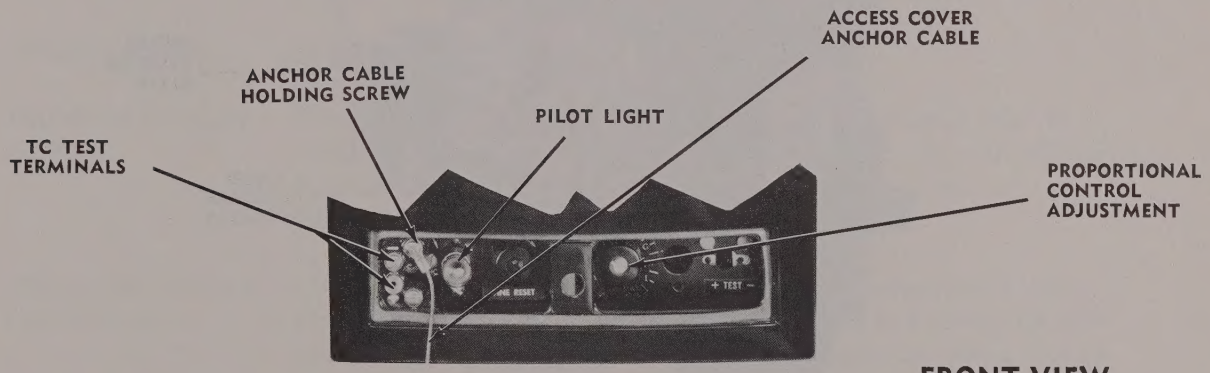
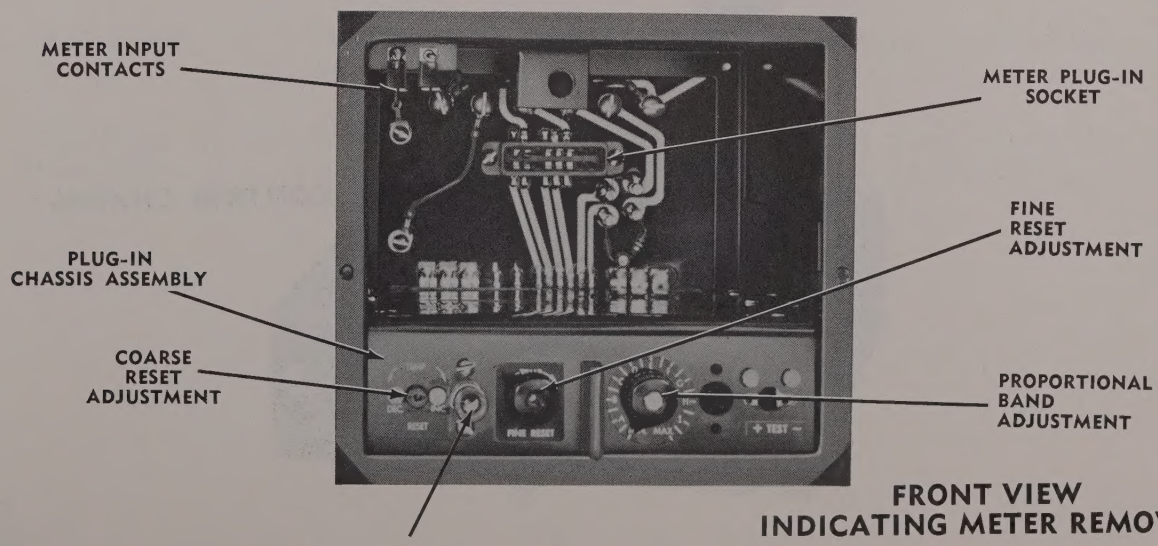
MODEL 357A DIGISET



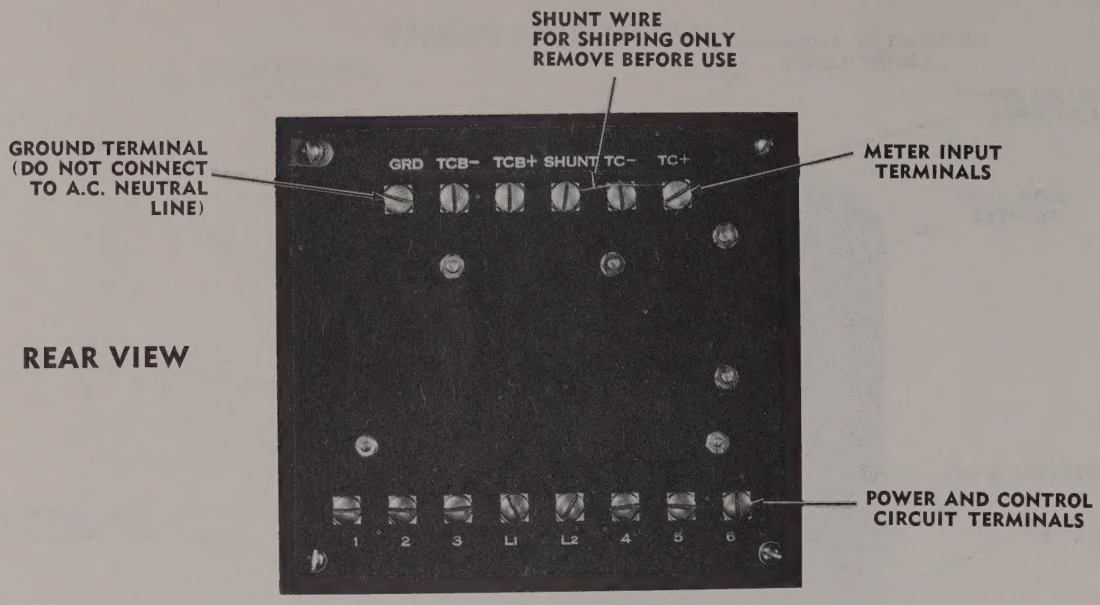
FRONT VIEW



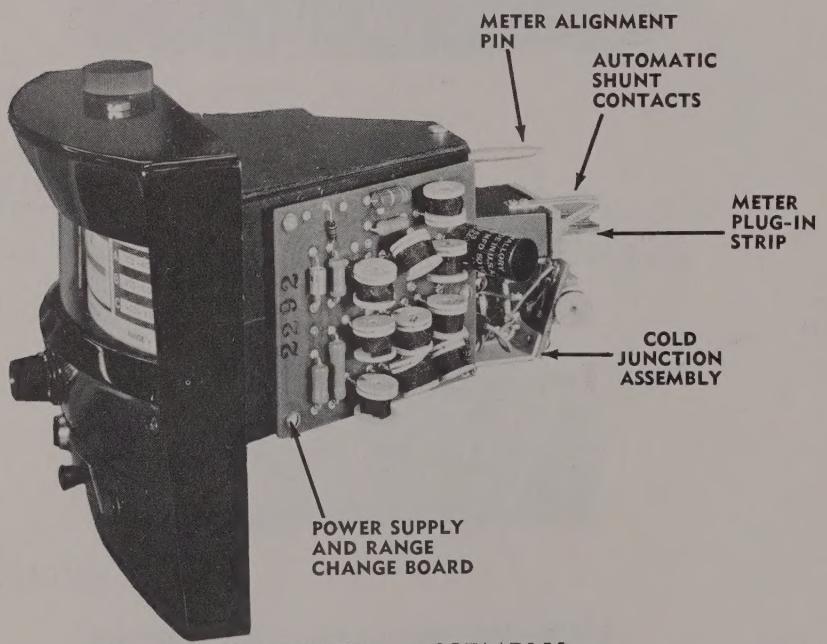
FRONT VIEW
ACCESS COVER REMOVED



FRONT VIEW
INDICATING METER REMOVED



REAR VIEW



INDICATING METER ASSEMBLY

CONTROL CHASSIS

F-12593
Ref. 3-65

DEFINITION OF TERMS

CONTROL SET POINT	The position on the instrument scale to which the control point setting mechanism is set.
CONTROLLED VARIABLE	That quantity or condition which is varied by the controller so as to affect the power of the measured variable. Example: Power to an electric furnace.
CYCLING	A periodic change of the measured variable from one value to another. Oscillation and hunting are synonymous terms.
FINAL CONTROL ELEMENT	That portion of a control system which directly changes the value of the controlled variable. Example: Model 621A Power Controller.
MEASURED VARIABLE	That quantity or condition which is measured and regulated through control of the controlled variable. Example: Temperature in a furnace.
OFFSET	A sustained deviation from control point due to proportional control action. It is the difference existing at any time between control point and the actual value of the measured variable. Droop is a synonymous term.
OSCILLATION	See Cycling.
PROPORTIONAL BAND	That change in value of the measured variable that is necessary to cause full travel of the final control element. It is measured as a percent of full scale span. Throttling range is a synonymous term.
PROPORTIONAL CONTROL	Controller action in which there is a continuous linear relation between the value of the measured variable and the position of the final control element. In other words, the output of the controller is proportional to its input. Synonymous terms are throttling or modulating action.
RESPONSE TIME	The time for the meter indicator to reach 63.2% of the final value after a step change input.
CRITICAL DAMPING	That condition of damping in which the meter movement reaches the point of equilibrium in the least possible time without overshoot.

SPECIFICATIONS

Meter Assembly

a. Meter

Scale Length	30 millimeters or 30 divisions 1 division = 1 millimeter
Sensitivity	0.44 microamps per division (nominal)
Internal Coil Resistance	95 ohms (nominal)
Critical Damping Resistance	275 ohms (nominal. Added by using potentiometer in the TC measuring circuit. Supplied for use with base metal thermocouples only (optional)
Response Time (63.2%)	
w/o Damping Resistance	5.5 seconds (nominal)
Critically Damped	1.4 seconds (nominal)

b. Reference Voltage Source (R.V.S.)

Output Resistance	50 ohms (nominal)
Ranges	See table at back of manual
Line Voltage Stability	± 10% line change results in R.V.S. output change of 3 microvolts or less
Electrical Cold Junction Compensation	Incorporated on all temperature ranges, and some millivolt ranges
Adjustable Output	Ten turn linear precision potentiometer with dial lock
Calibrated Accuracy	One-half percent of full scale value. Reading accuracy also depends on thermocouple linearity and tolerance. See page 34.

c. Thermocouple Break Protection — Furnished as standard. May or may not be used, as desired.

Control Chassis

Control Output	Direct current
Control Output Span	2 to 12 milliamperes into 1500 ohm load
Proportional Band	Adjustable from 2.2 to 17% of scale length (17% = 5.1 div.; 2.2% = 0.6 div.)
Control Adjustment	Reset internally adjustable to correct for offset
Power Supply	110-130 volts a-c, 50/60 cycle
Power Requirements	9 va

Dimensions and Weights

Overall Dimensions	6 7/8" wide x 6 1/4" high x 9 5/8" deep
Cutout for Flush Mounting	6 1/8" wide x 5 9/16" high. Meter will extend 7 1/4" into panel when flush mounted
Weights	Net - approximately 10 pounds Shipping - approximately 15 pounds

DESCRIPTION

General Description and Application

The Digiset is a millivoltmeter type null balance indicating controller with a proportional current output. Incorporated in the instrument is a reference voltage source which has a digital setpoint to obtain the desired operating temperature or millivoltage setting. The reference voltage source output is connected in series with the measuring thermocouple so the potential difference between the reference voltage and the thermocouple determines the indicator deflection from the null balance point and therefore the d-c output of the controller. The instrument is used as the primary control instrument for controlling magnetic amplifier/reactor systems or silicon controlled rectifier power controllers for the proportional control of load power.

The unit uses solid state devices and, when specified, electrical cold junction compensation associated with the desired thermocouple. Other features of the instrument include one degree setability of control set point, multiple range selection and a potentiometer (for base metal thermocouples only) to adjust the thermocouple measuring circuit resistance, controlling sensitivity and damping of the meter indicator. Operating on the null balance principle, the effect of thermocouple extension wire is negligible. Thermocouple break protection is provided, to be used or not as desired. The instrument has been designed to meet the demand for an accurate and dependable instrument of small size.

Control Specifications

As stated above, the Model 357A Controller has a proportional direct current output for controlling magnetic amplifiers or silicon controlled rectifier power controllers. Magnetic amplifiers are generally used to control saturable core reactors, which in turn regulate the load power. The output range of the Model 357A is 2 to 12 milliamperes and is designed to be used with a 1500 ohm load. Two adjustments, "Proportional Band" and "Reset" are adjustable from the front of the chassis. The proportional band is adjustable from 2.2% to 17% of graduated scale length. The control point is set so that when the meter indicator coincides with the red arrows in the center of the scale, the output of the instrument is approximately 7 milliamperes. If the load requirements are other than this the offset or deviation between the red arrows and the meter indicator is adjusted with the reset adjustment as described in a later section of this manual.

The red signal light indicates that power is applied to the chassis. The output terminals are terminals 5 and 6, with terminal 5 of negative polarity and terminal 6 positive.

Electronic Circuit

The Model 357A incorporates a transistorized oscillator and a d-c amplifier. At a position to the left of the red arrows, the collector current of the oscillator transistor is of sufficient magnitude so that the output of the d-c amplifier is greater than 12 milliamperes. As the indicator approaches the red arrows, a small vane or flag suspended from the indicating pointer passes between two flat coils, reducing the collector current of the oscillator transistor. With the flag fully between the coils, the collector current is decreased to a minimum so that the output of the d-c amplifier is less than 2 milliamperes. Proportional control action occurs when the flag traverses a fixed distance between the coils. The position of the flag within the coils, therefore, determines the collector current which then proportionately controls the amplifier output. The proportional band is made larger or smaller by adjusting the level of feedback from the d-c amplifier to the oscillator, regulating the oscillator collector current change with respect to flag movement. When there is no feedback, the proportional band is at minimum, or 2.2% of graduated scale length, and at maximum feedback the proportional band is increased to 17% of graduated scale length or greater.

Reference Voltage Source

The reference voltage source consists of a Zener regulated input to a bridge configuration which is designed to minimize the effects of line voltage changes and ambient temperature changes. The regulated output of the bridge supplies a calibrated voltage to oppose the thermocouple input and also energizes the electrical cold junction compensation network. Depending upon customer requirements, up to three adjustable output ranges are available. A ten turn linear precision potentiometer is used with the range selected to obtain the desired control set point value. A dial lock is also supplied so the setting of the unit remains fixed. The digital indication is from 0 to 999. The temperature or millivoltage can be determined by dividing the range span by 1000, giving the number of degrees or millivolts per digit. The ranges available are printed on the right side of the meter scale, with the range selector knob located just below the meter scale. The digital indication is shown on the left-hand side of the meter scale.

The output of the reference voltage source is linear. When calibrated for temperature degrees for a particular thermocouple calibration, the dial reading is not absolutely exact because thermocouples do not have linear potential output with respect to temperature. However, when small temperature spans are utilized the error is diminished. The Model 357A is calibrated so as to give an output approximating the curve and intersecting the curve at two or more points. See Figure 1. In the example shown (0-800°F range using Plat./Plat. 13% Rho.), the midrange of the thermocouple EMF is + 1.794 mv. This is equivalent to 458°F. With a linear millivoltage output of the instrument, tracking line B as shown on the graph, this amount of millivoltage will read out as 429°F. Thus the

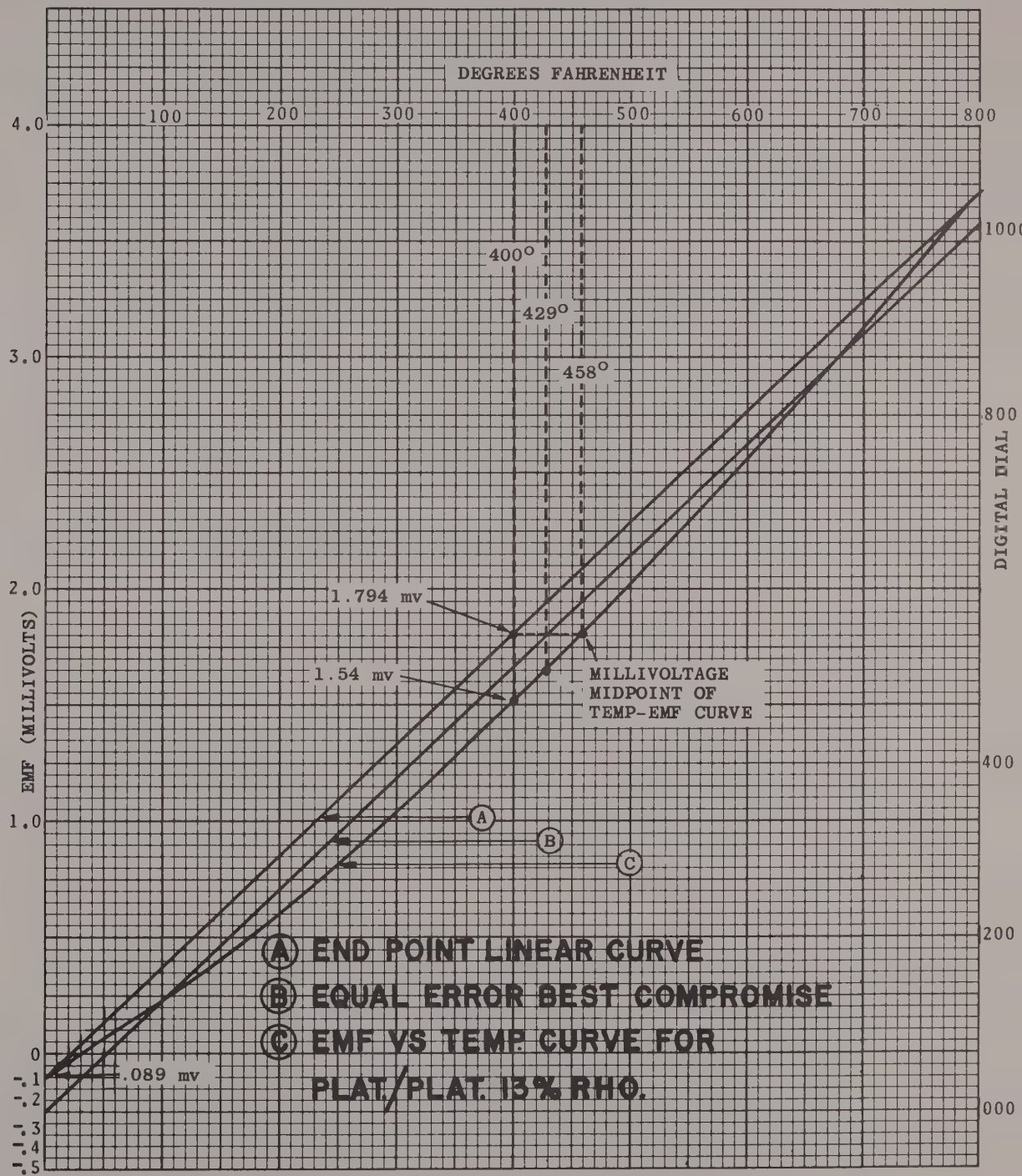

DEGREES FAHRENHEIT
100
200
300
400
500
600
700
800
4.0
3.0
2.0
1.0
0
-.1
-.2
-.3
-.4
-.5
EMF (MILLIVOLTS)
1000
800
400
200
000
DIGITAL DIAL
400°
429°
458°
1.794 mv
1.54 mv
MILLIVOLTAGE
MIDPOINT OF
TEMP-EMF CURVE
A
B
C
.089 mv
Ⓐ END POINT LINEAR CURVE
Ⓑ EQUAL ERROR BEST COMPROMISE
Ⓒ EMF VS TEMP. CURVE FOR
PLAT/PLAT. 13% RHO.

Fig. 1

instrument is in error by 29°F, on the low side, at the midpoint of the range. It can be seen that as the cross-over points are approached the error becomes less, eventually reaching zero, but at either extreme end of the range the error is again maximum although of opposite sign.

NOTE: The 0-800 Plt/Plt 13% Rho. example is an extreme case and is only intended to illustrate the TC non-linearity and linear calibration method. This example also illustrates that 800° cannot be reached with this calibration and range. Ranges should be specified to cover temperatures required. Refer to range tables for actual recommended ranges.

Instruments calibrated in millivolts, with cold junction temperature compensation, are preferred for many applications since problems of thermocouple non-linearities are not encountered. The only inaccuracies present would be those due to production tolerances or thermocouple limits of error. However, when using an instrument calibrated in millivolts, it is necessary to refer to a thermocouple-millivoltage table to determine the millivolts required for a desired temperature. Ask for a "Conversion Data Handbook", form F-10341, from your Barber-Colman sales engineer.

The list of Model 357A standard ranges at the back of this manual also shows the thermocouple non-linearity error for each temperature range and calibration.

Proportional Control

Within the proportional band, the Model 357A will supply an output to an external power controller which is proportional to temperature deviation. Barber-Colman external power controllers are generally designed so that when 12 milliamperes are supplied from the controlling instrument, maximum power is applied to the load, and when 2 milliamperes are supplied, minimum (or zero) power is applied to the load. A means of close tolerance control of load power, with minimum overshoot and undershoot, is therefore obtained.

Figure 2 is an example showing the instrument's proportional band curves for a 17% proportional band setting and a 2.2% proportional band setting. The 17% proportional band setting is obtained by turning the proportional band adjustment fully clockwise. Also, in Figure 2 are the Model 621 or 622 and Model 610A power transfer curves. The power transfer curves also assume that the input control winding resistance of the 610A and 621 or 622 Models is 1500 ohms. The curves give a relative indication of power output. For example, if a voltmeter was attached to the test jacks and the meter read 12 volts (8 ma with 1500 ohm load) the 621 or 622 power output would be 60% of maximum output power. If a Model 610A was used the output of the 610A would be about 42.5 volts d-c, which would be the input to a reactor used in conjunction with the 610A magnetic amplifier.

As shown in the example, the meter would indicate about 0.5 of a division to the left of the red arrow. This offset is corrected using the reset adjustment as described under "Control Adjustments". The example shows the proper reset adjustments for the particular control point selected. In this example, the power transfer curves would also be shifted over the same amount as the proportional band curve.

To obtain the number of degrees (Fahrenheit or Centigrade) represented by the effective proportional band, the two examples discussed in the section entitled "Thermocouple Circuit Resistance" are utilized:

For a proportional band setting of 17% of scale length, the proportional band in °C for the two examples would be:
(see page 22 for determination of degrees/division)

Meter coil plus R.V.S. resistance (not critically damped)

4.75°C/division x 17% x 30 divisions/scale length = 24.2°C

This means that a 24.2°C change in temperature will change the control output current from 12 to 2 milliamperes in the proportional band operating range.

Critically damped:

13.5°C/division x 17% x 30 divisions/scale length = 68.8°C

For proportional band setting of 2.2% of scale length:

Meter plus R.V.S. resistance (not critically damped):

4.75°C/division x 2.2% x 30 divisions = 3.1°C

Critically damped:

13.5°C/division x 2.2% x 30 divisions = 8.9°C

In some cases the temperature change that is required to change the controller output from 12-2 ma might not be sufficient for adequate control. If this is the case, by increasing the thermocouple circuit resistance (see page 21), the effective proportional band related to temperature change will be increased or the meter sensitivity decreased. Generally, the maximum proportional band should be equal to a temperature change of 5% of span to insure adequate control. The temperature in degrees per division can then be obtained for a maximum proportional band condition by dividing 5% of the temperature span by 5.1. The external resistance needed can then be determined from the nomograph on page 24.

In using the 357A in control systems, the proportional control of load power is obtained by using the direct current output of the instrument to control a pilot amplifier/saturable reactor combination, or a Model 621 or 622 "SCR" power controller. The external wiring diagrams show typical connections. If reactors are used to control load power, a shunting resistor should be connected directly across the reactor control winding terminals, as shown, in order to protect the reactor control winding in case the control circuit is opened under load, inducing a high voltage in the control winding.

As can be seen in Figure 2, there is always a small output when using a Model 610A Pilot Amplifier to drive a reactor. This results in a small amount of power always being applied to the load, even when the instrument's output is less than 2 milliamperes. Two types of pilot amplifiers are available for the pilot control reactors: The Model 610A -- a magnetic amplifier, and the Model 630A -- an SCR type controller with a d-c output. The specifications are as follows:

Model 610A	Excitation 120 v, 60 cycle; output - 5-75 v d-c, maximum power output to reactor control windings - 188 va. Used with reactors up to 30 kva rating.
Model 630A	Excitation 120 v, 60 cycle; output - 0-80 v d-c, maximum power output to reactor control windings - 750 va. Used with reactors up to 130 kva rating.

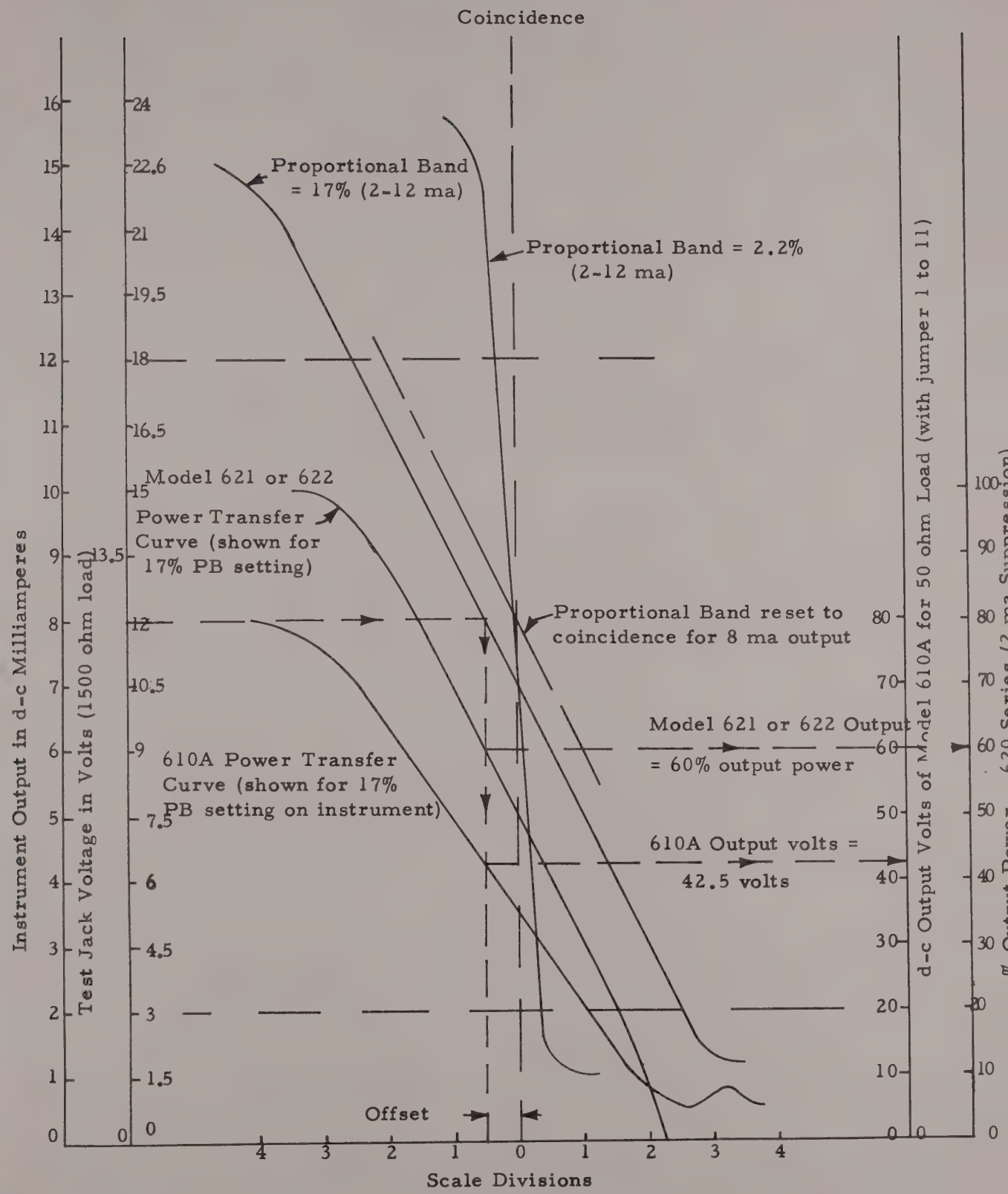

Coincidence
Proportional Band = 17% (2-12 ma)
Proportional Band = 2.2% (2-12 ma)
Model 621 or 622 Power Transfer Curve (shown for 17% PB setting)
Proportional Band reset to coincidence for 8 ma output
Model 621 or 622 Output = 60% output power
610A Power Transfer Curve (shown for 17% PB setting on instrument)
610A Output volts = 42.5 volts
Offset
Instrument Output in d-c Milliamperes
Test Jack Voltage in Volts (1500 ohm load)
d-c Output Volts of Model 610A for 50 ohm Load (with jumper 1 to 11)
Scale Divisions

Figure 2
Example of Proportional Control Action as the Meter Indicator Moves to the Right Through the Proportional Band

INSTALLATION

Unpacking the Instrument

This precision instrument and its associated equipment have been carefully manufactured and packed at the factory. Remove the instrument and accessories from the packing box and check items against the packing slip. If the equipment is found to be damaged in transit, report damages to the carrier immediately. Repack in original packing box until ready for installation.

CAUTION:

Handle with care.
Safeguard instrument from shock before and after installation.
Avoid oil accumulation and exposure to moisture.
Keep instrument temperature under 130°F and over 40°F.

Mounting Instructions

Locate instrument to avoid excessive vibration, shock, and temperatures outside the range of 40°F to 130°F. Avoid furnace walls, radiation of heat, machine frames, and outside walls. Provide suitable shelter against moisture and temperature extremes if installed outdoors. Refer to appropriate drawing for mounting details.

Power Wiring

The Model 357A is to be powered from 110-130 volt only, 50 or 60 cycle a-c systems. The a-c supply voltage is connected to terminal L1 and L2 on the back of the instrument housing. All wiring should be in accordance with the applicable electrical codes. Where maximum protection of the instrument is desired, a 1/8 ampere slow blow fuse may be added in the power line to the instrument.

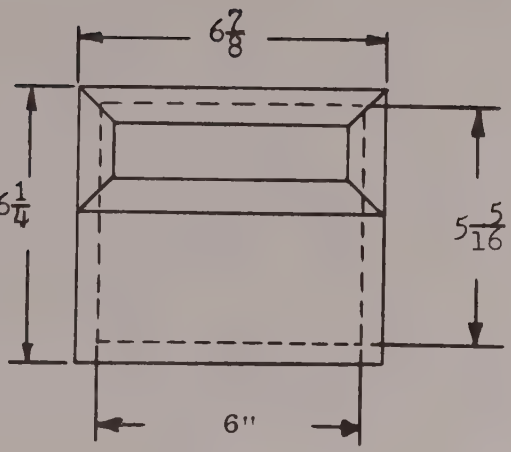
The instrument should be grounded. This is accomplished by attaching the ground terminal directly to a good ground, such as a cold water pipe.

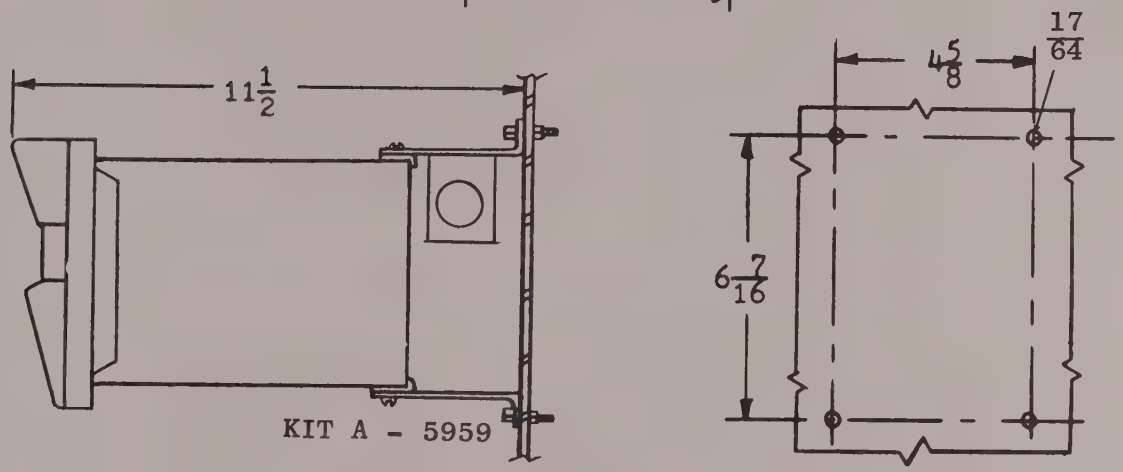
CAUTION:

Do not connect the GRD terminal to the neutral a-c line.

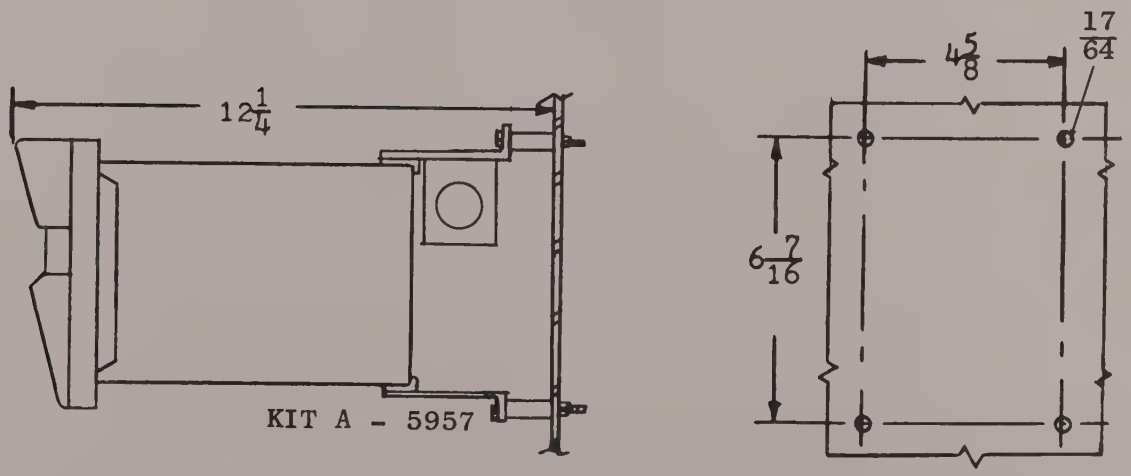
Terminals 5 and 6 are wired internally to the control chassis to obtain a d-c output current. Terminal 6 is the positive terminal, and terminal 5 is the negative terminal. The external wiring diagrams show some typical wiring diagrams.

FRONT VIEW AND
CASE DIMENSIONS



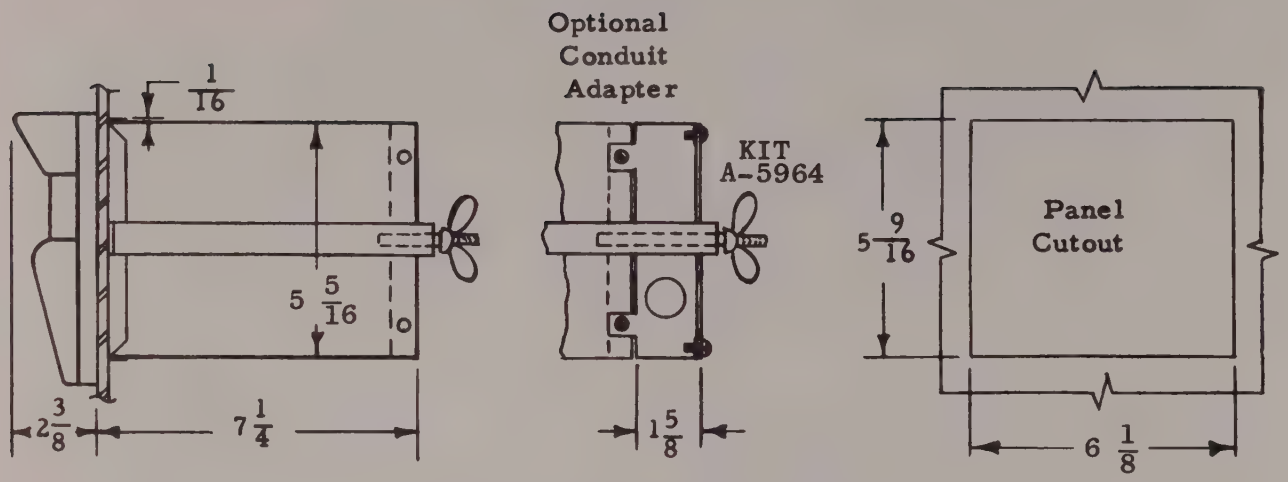


SURFACE MOUNTING DIMENSIONS

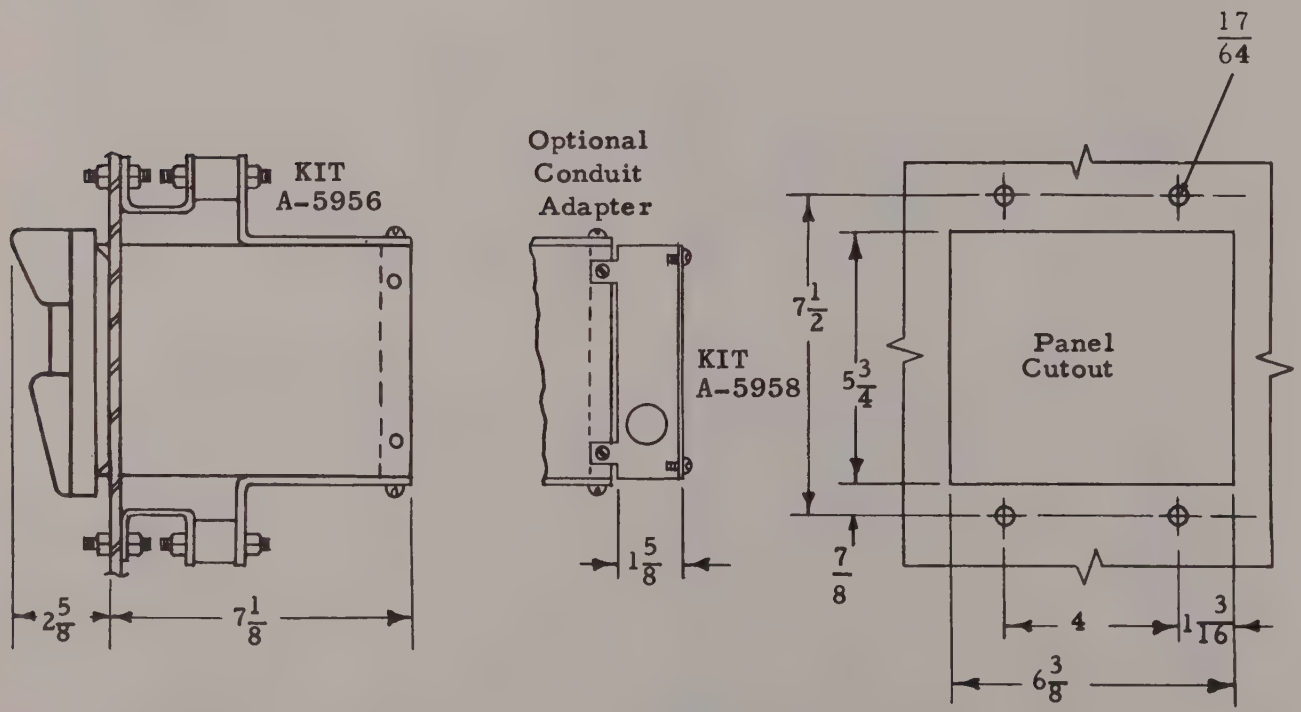


VIBRATION MOUNTING ARRANGEMENT FOR SURFACE MOUNTING

Figure 3



FLUSH MOUNTING DIMENSIONS



VIBRATION MOUNTING ARRANGEMENT FOR FLUSH MOUNTING

Figure 4

Meter Shunt Wire

After the instrument is installed, disconnect the jumper wire across terminals marked "Shunt", "TC-"and "TC+" on the back of the instrument. This wire is used to shunt or dampen the meter movement for protection during shipping, handling and installing the instrument, but should be removed for normal operation.

If the meter assembly is removed from the case, the automatic shunt device protects the meter assembly from damage. Shunt wiring is not required.

Thermocouple Wiring

Do not run thermocouple extension wire with other power or control wiring. Several thermocouple extension wires may be run in the same conduit, however.

Use only extension wire correct for the type of thermocouple (TC) as specified on the scale. The types most commonly specified are:

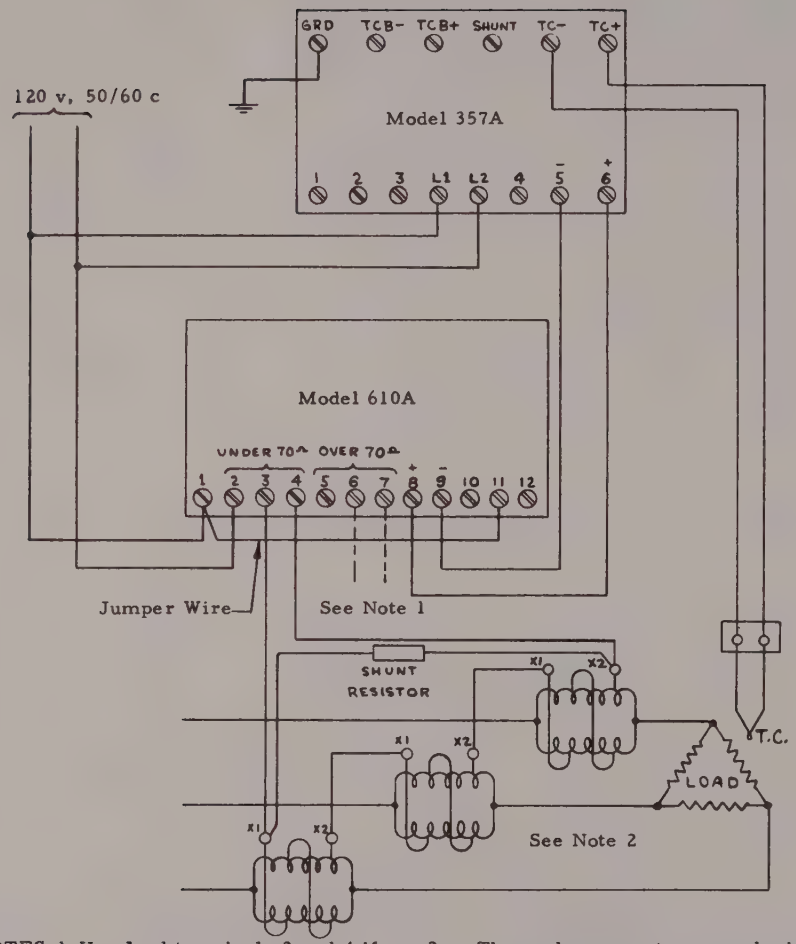
Iron-Constantan	Type J
Chromel-Alumel	Type K
Platinum-Platinum 10% Rhodium	Type S
Platinum-Platinum 13% Rhodium	Type R

Ordinary copper wire must not be used as extension wire. Consult your Barber-Colman field office for a selection of thermocouple assemblies and extension wire.

Thermocouple connections are made between the thermocouple head and TC terminals on the back of the instrument housing. Connect plus to plus and minus to minus, using the proper polarity and calibration of extension wire. Color coding red indicates the negative wire. If connections are made correctly, the indicating pointer will move to the right when the thermocouple hot junction is heated to a temperature higher than the equivalent setting of the digital set point. If it does not, set the reference voltage source to minimum voltage, disconnect the thermocouple, twist the ends of the extension wire together and heat this junction to a temperature sufficient to cause meter deflection. A left-to-right deflection of the indicator is proof of correct polarity of the extension wire, which means that the connections at the thermocouple head were reversed.

NOTE: The above means of checking polarity can apply only when the minimum range is zero or slightly over.

Secure the extension wires firmly under the terminal screws. Spade lugs may be used. If desired, the thermocouple output can be monitored by using the TC check terminals to the left under the front access cover.



NOTES: 1. Use load terminals 3 and 4 if reactor X1-X2 winding resistance is between 30 and 70 ohms. Use load terminals 6 and 7 if resistance is between 70 and 150 ohms.

2. Three phase reactors may be individually shunted. Reactor d-c coils may be parallel connected in special cases. Refer to manufacturer's specification sheets accompanying reactor.

Figure 5

External Wiring Diagram of Model 357A
Used to Drive a Three-Phase Saturable Core Reactor System
Through a Model 610A Pilot Amplifier

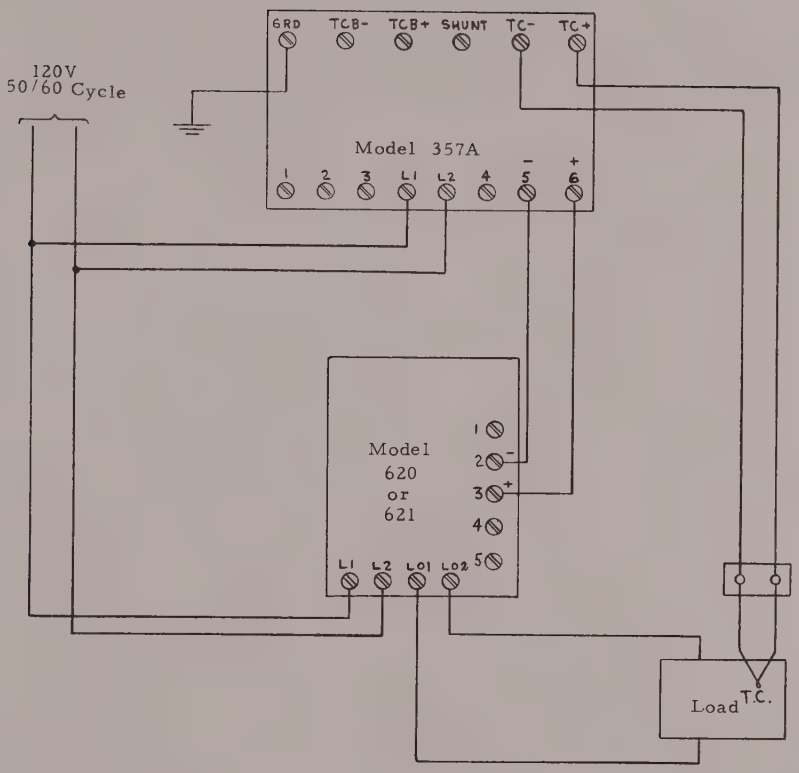
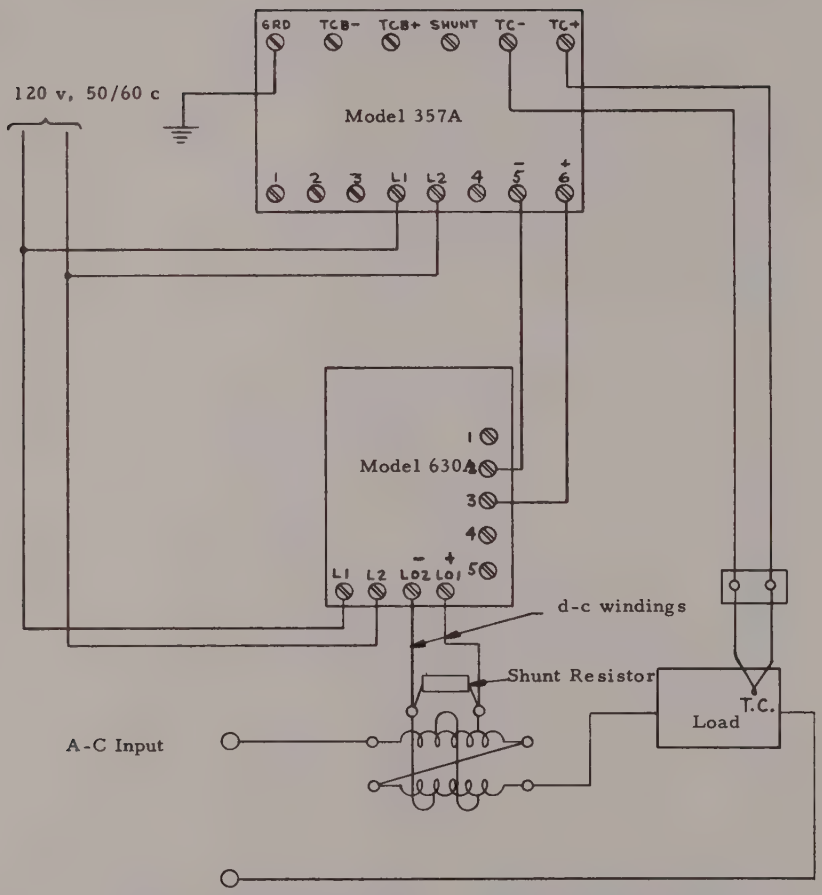


Figure 6

External Wiring Diagram of Model 357A
Driving a Series 620 SCR Power Controller



NOTES: 1. Reactor coils may be parallel connected for lower line voltage. Refer to manufacturer's specifications.

2. Identification of control winding terminals differ with various manufacturers.

Figure 7

External Wiring Diagram of Model 357A
Driving a Saturable Core Reactor Through a Model 630A
SCR Pilot Amplifier

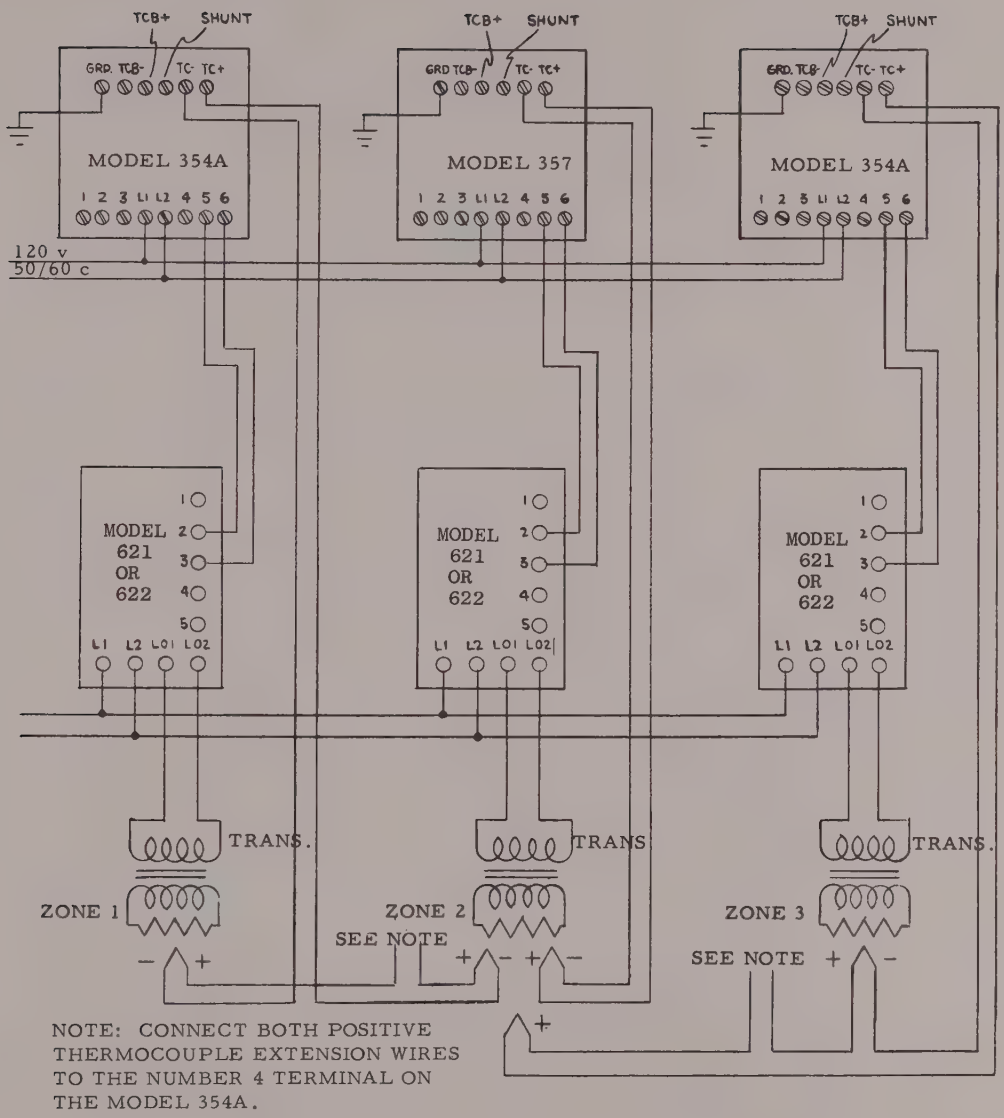
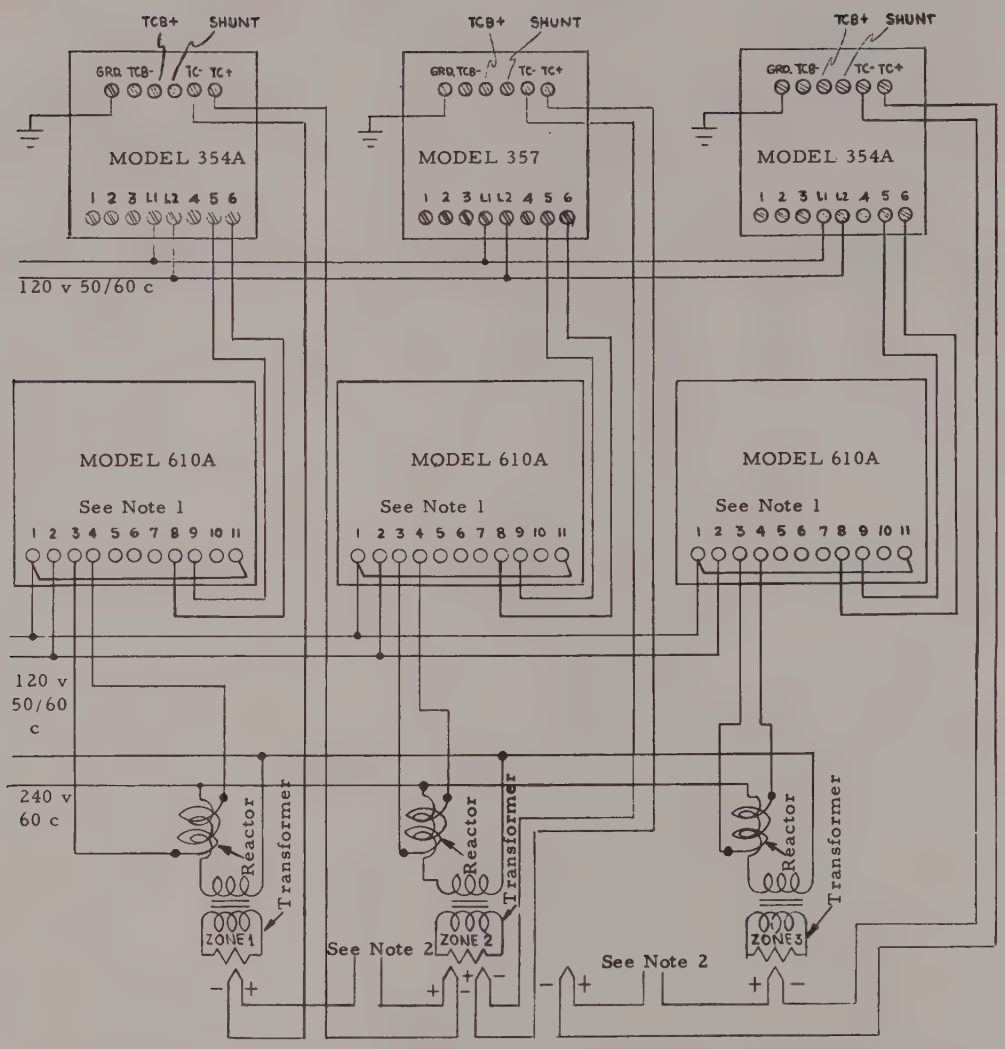


Figure 8

External Wiring Diagram Showing a Model 354A
Used in a Master-Slave System with a Model 357 Digiset
for Differential Control Through Model 621 or 622 Power Controllers

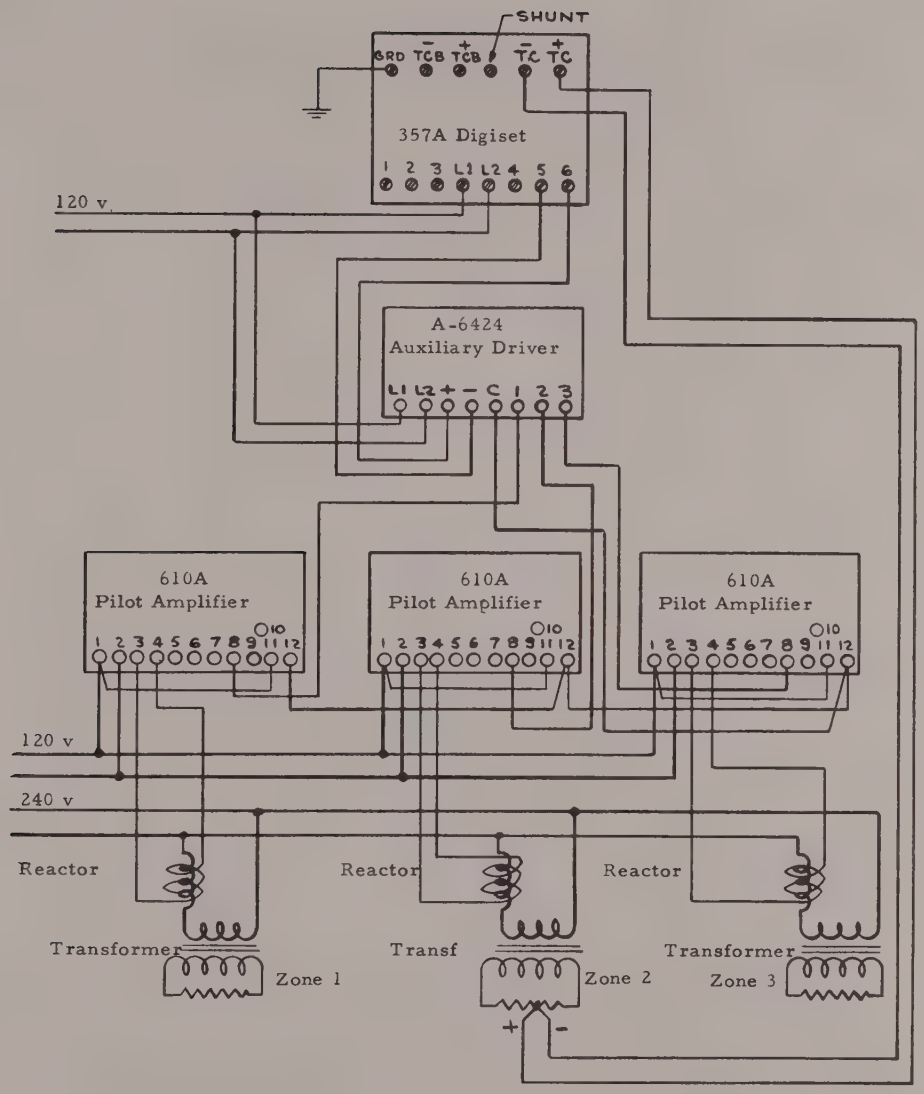


NOTES:

1. If impedance of reactor d-c control winding is over 70 Ω connect to terminals 6 and 7 of 610A. If under 70 Ω connect to terminals 3 and 4.
2. Connect both positive thermocouple extension wires to the number 4 terminal on the Model 354A.

Figure 9

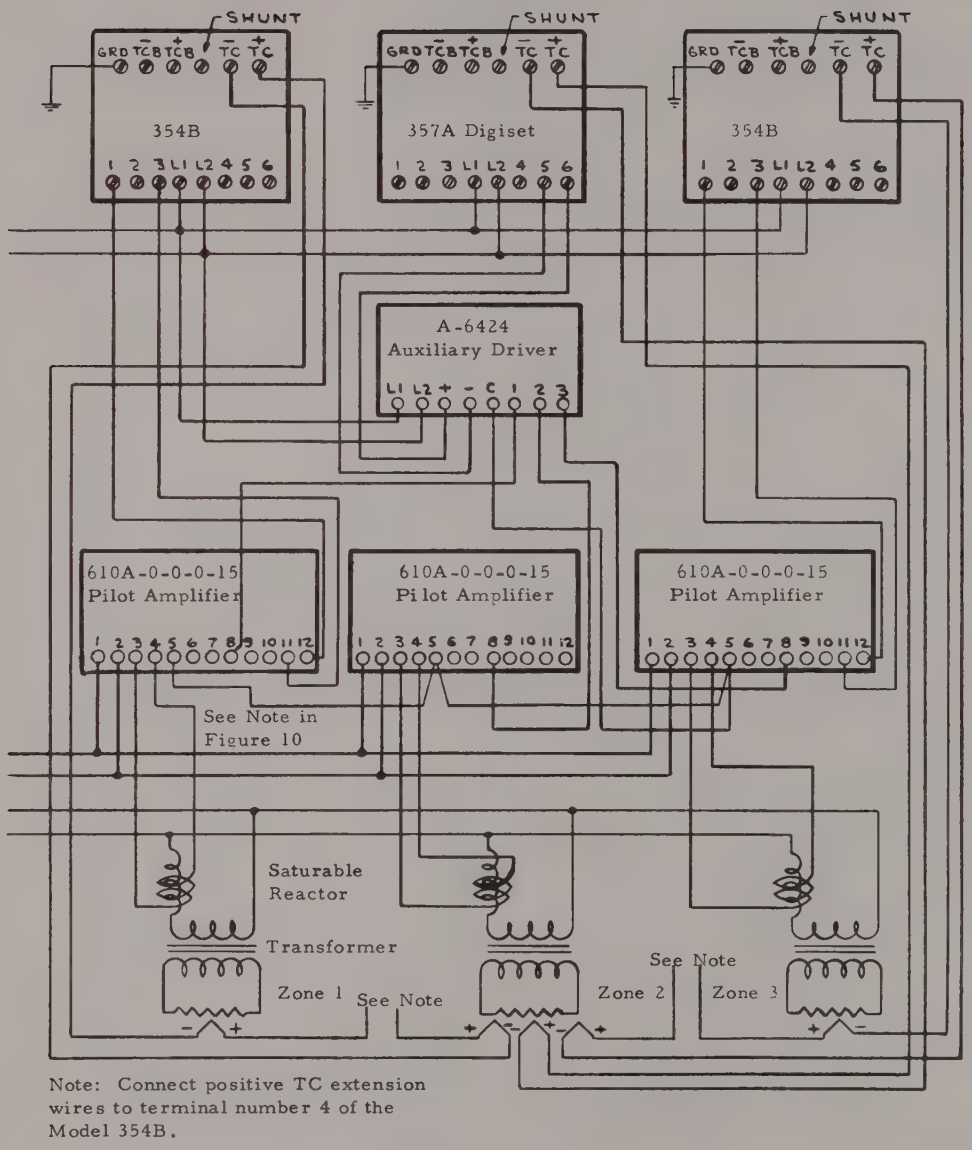
External Wiring Diagram Showing the Model 354A Used in a Master-Slave System with a Model 357 Digiset for Differential Control Through a Model 610A Pilot Amplifier and Saturable Reactors



NOTE: If impedance of reactor d-c control winding is over 70 ∩ connect to terminals 6 and 7 of 610A. If under 70 ∩ connect to terminals 3 and 4.

Figure 10

External Wiring Diagram Showing the Model 357A in a Differential Control System Using an Auxiliary Driver for Three Pilot Amplifiers and Saturable Reactors



Note: Connect positive TC extension wires to terminal number 4 of the Model 354B.

Figure 11

External Wiring Diagram of the Model 357A with two Model 354B's in a Locked Differential System for Three-Zone Control. An auxiliary Driver is Used with Three Special Model Pilot Amplifiers (equipped with an auxiliary control and adjustable bias windings) and Saturable Reactors

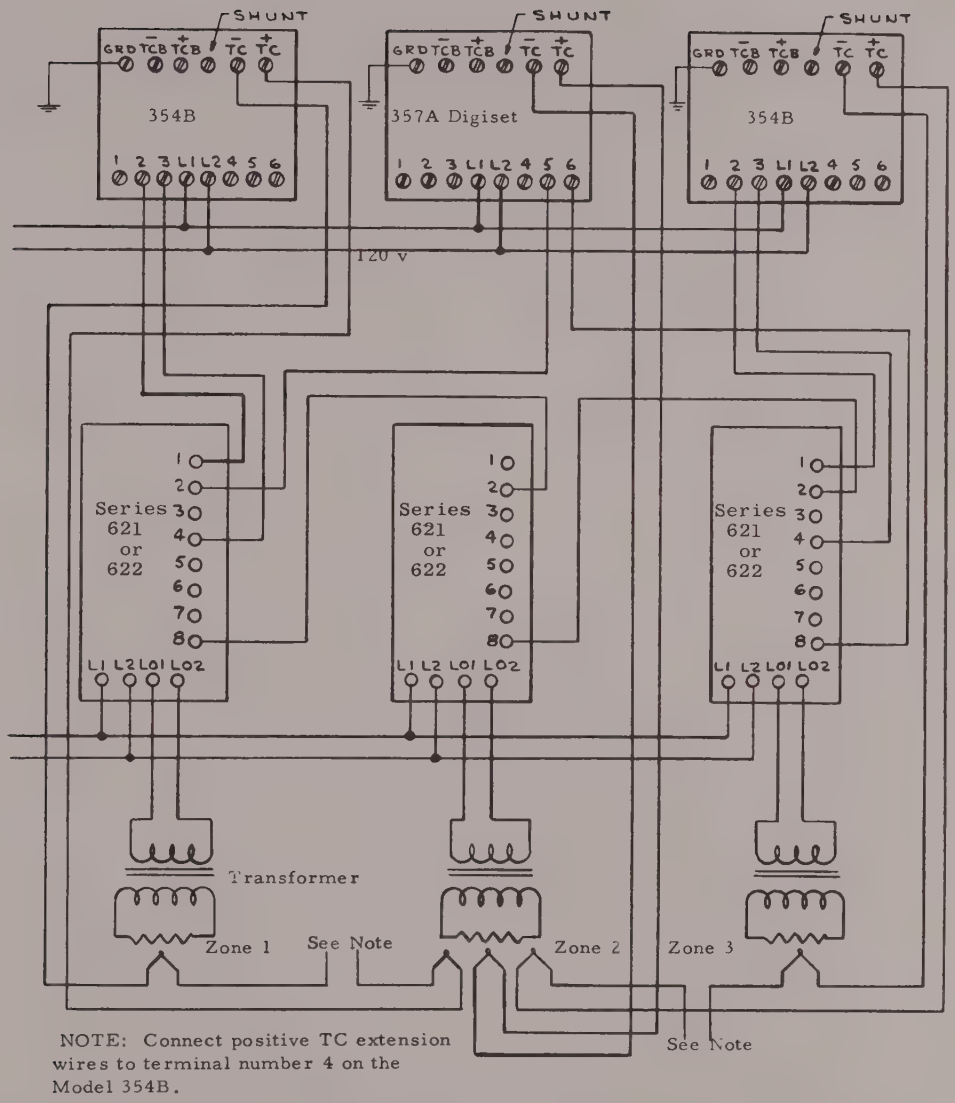


Figure 12

External Wiring Diagram Showing the Model 357A with Two Model 354B Locked Differential Systems for Three-Zone Control Through Three SCR Power Controllers

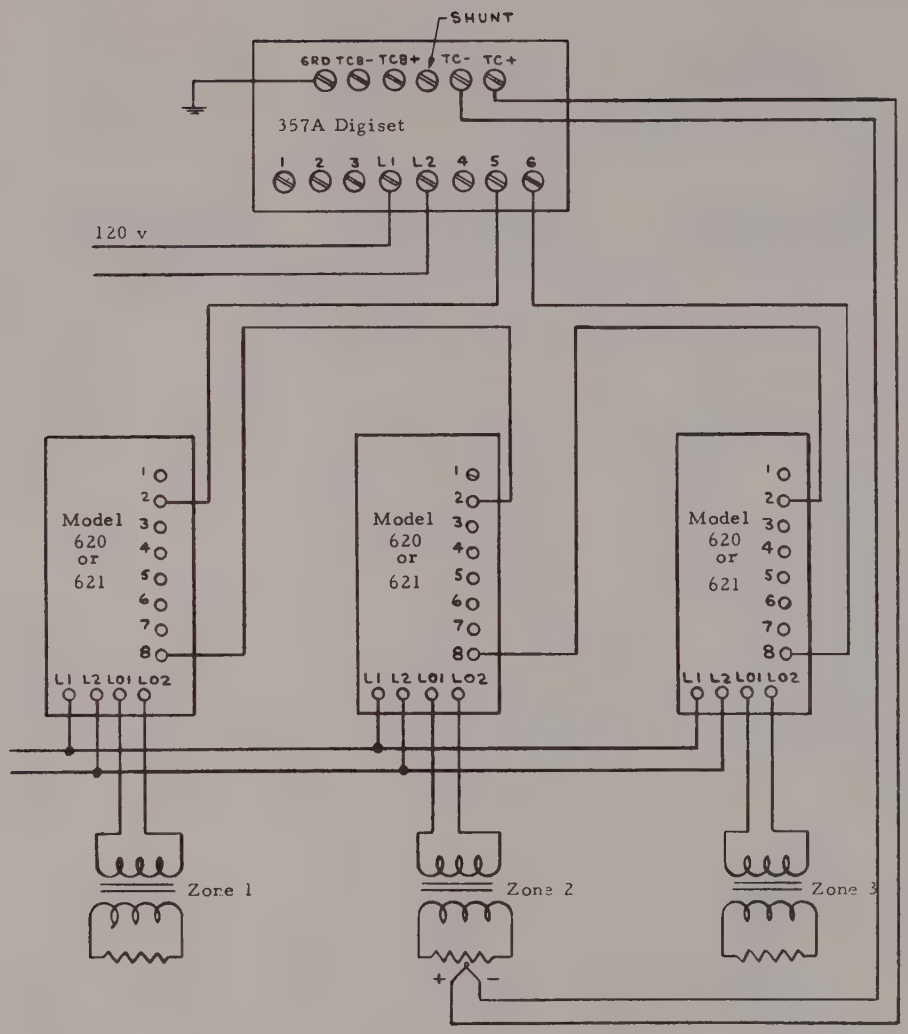


Figure 13

External Wiring Diagram Showing the Model 357A Controlling Three Zones from a Central Zone Using SCR Power Controllers

Cold Junction Compensation

For measuring temperature, thermocouples are the most commonly used sensing devices. They produce a voltage when there is a temperature difference between the "hot" or measuring junction and the "cold" junction located in the meter assembly. Since the difference in temperature between the hot and cold junctions determines the amount of millivoltage produced, it is necessary to keep the cold junction temperature constant, or to compensate for any changes that occur at this point. The Model 357A compensates for temperature changes at the cold junction electrically and automatically. Electrical cold junction compensation is accomplished by utilizing the resistance change, due to temperature, of a resistor. The resistance value would depend on the type of thermocouple used. Electrical cold junction compensation is furnished with most instruments, but may be omitted for special millivoltage measurement applications. See table of standard ranges listed in the back of this manual.

Thermocouple Circuit Resistance

Since the Model 357A utilizes a null balance arrangement in conjunction with a sensitive meter movement, the resistance of the thermocouple and lead-wire has only a negligible effect on the controller. Such effect as it may have takes the form of altering slightly the response time or the sensitivity of the instrument. The greater the thermocouple measuring circuit resistance, the faster will be the meter response but with a decrease of sensitivity. In many applications, particularly with use of base metal thermocouples, additional resistance is added in series with the thermocouple input to increase the response of the meter (decreasing the response time) or to decrease the meter sensitivity. To add resistance to the measuring circuit, a 500 ohm potentiometer mounted inside the case on the back wiring panel may be adjusted to the desired additional resistance.* (Each graduation on the scale represents approximately 50 ohms). As shipped, the resistance potentiometer is set for zero resistance.

To obtain critical damping (the point at which the meter will reach control point in the least possible time without overshoot), 275 ohms resistance is added to the thermocouple measuring circuit. This is a setting of 5.5 on the potentiometer scale. The response time of the unit is thus reduced from 5.5 seconds to 1.4 seconds. As stated previously, the added resistance will decrease the sensitivity. This means that the microvolts required to cause the meter indicator to deflect one scale division is increased.

*Supplied only with instruments using base metal thermocouples.

The microvolts required to deflect the pointer one division can be determined from the nomograph (Figure 14). It is used in the following manner:

1. Determine the total thermocouple circuit resistance of the meter. This is the combined resistance of the meter coil (95 ohms), thermocouple and extension wire, the potentiometer resistance inside the back panel, and the reference voltage source (50 ohms). Total resistance can be figured by adding the value of each of these elements, or else by measuring the external resistance with an ohmmeter. To do this, remove the meter assembly and attach the ohmmeter leads to the TC connector springs, and then add the 95 ohms coil resistance and 50 ohms R.V.S. resistance to the value measured.

2. With the total resistance then known, draw a line from that resistance value through point A on the nomograph, intersecting the μv/division line, giving the microvolts per division.

3. If the degrees Fahrenheit or degrees Centigrade per division is desired, draw a line from the intersecting point on the μv/division line through point B, C or D, depending upon the thermocouple used, intersecting the °F or °C/division line, thereby giving the Fahrenheit or Centigrade degrees per division.

The two examples shown neglect the thermocouple and extension wire resistances. One example is for a meter with coil resistance plus R.V.S. resistance, which is 145 ohms, and the other example applies to a unit that is critically damped (95 + 50 + 275 ohms). The sensitivity is shown to be 63.8 and 184.8 μv/division respectively. If a Pt/Pt 13% TC were used, this would result in 4.75°C/division for the coil plus R.V.S. and 13.5°C/division when the unit is critically damped.

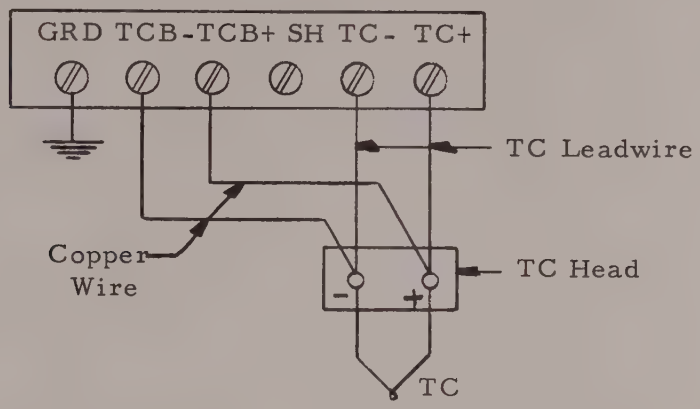
See section on "Proportional Control" for the effective proportional band.

Thermocouple Break Protection

The instrument is equipped with thermocouple break protection (TCB) to be used if desired. This protection is provided by utilizing a small d-c voltage that can be wired into the thermocouple circuit so that, in the event of an open thermocouple circuit, the meter indicator is driven to the right of the red arrows causing the output of the instrument to be decreased to its minimum value, thereby causing the output of the power controller to be at minimum power output.

The instrument will operate in a normal manner without TCB connected, but its usage may be desired on some applications to guard against overheating in the event of an open thermocouple.

The following diagram shows the connections necessary for TCB to be operative. Normally 16 to 20 gauge copper wire is used for the TCB connections. Wiring for TCB may be run in the same conduit with thermocouple wire.



To check for TCB operation, disconnect the thermocouple to simulate a broken thermocouple but leave the TCB wires connected. When the instrument is powered, TCB is functioning properly if the indicator is driven to the right of the red arrows causing the control output of the instrument to go to minimum.

When TCB is utilized a slight error is introduced into the measuring system. This can be checked and compensated for in the following manner: With the instrument powered, and with the thermocouple maintained at a steady temperature, disconnect one of the TCB lead-wires and notice if there is any slight meter indicator movement. If there is, note the scale position of the meter indicator and then reconnect the TCB lead. Next, adjust the screw on the top of the meter housing until the meter indicator is at the same position it was when TCB was disconnected. Compensation for TCB error has then been made.

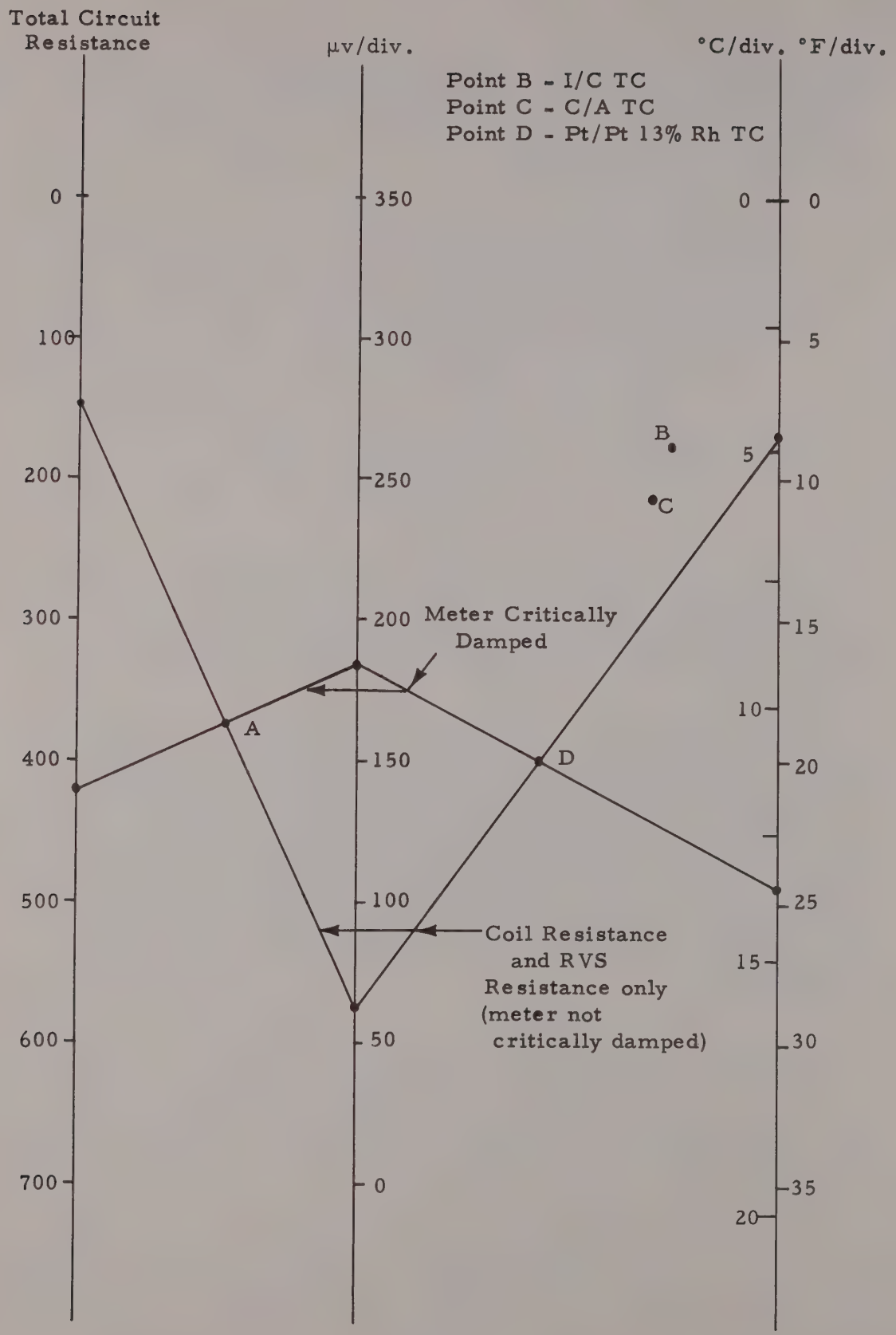


Figure 14
Nomograph of Meter Resistance vs Sensitivity

OPERATION

The meter indicator indicates the difference between the thermocouple input and the reference voltage source. When no difference exists the meter indicator coincides with the red arrows. The Model 357A has an instantaneous response because solid state devices operate without warm-up time. When the red signal light glows, the instrument is powered and the light will remain on until the power to the instrument is turned off. If a d-c voltmeter is connected across the test jacks, and with the output of the instrument connected to a controller, the voltmeter will show the output decreasing when the meter indicator moves from left to right, approaching the red arrows. This is the region where proportional control action occurs.

Meter Adjustment

Alignment:

Only one adjustment is necessary to align the meter indicator with the points of the two red arrows on the meter scale. This is done by opening the thermocouple circuit and then adjusting the alignment screw on the top of the instrument until the meter indicator coincides with the center of the meter scale indicated by the two red arrows. Turn the alignment screw slowly, allowing time at each turn for the indicator to reach equilibrium. The meter is then properly adjusted irrespective of changes in ambient temperature.

If correction for the effect of TCB is necessary, refer to page 23.

Set Point Adjustment:

The control set point temperature or millivoltage is set and indicated by the three digit dial to the left of the scale by the reference voltage source potentiometer. If the instrument is dual or triple range, the knob located below the scale must first be turned to the selected range. The red button on top of the meter is then depressed, releasing the dial lock on the set point knob, so the knob may be turned to the desired setting. After the temperature or millivoltage control point is set, the dial lock button is returned to its up position, holding the knob against accidental turning.

The temperature in degrees, or millivolts, per digit of the dial (units per digit) is obtained by dividing the selected range span by 1000. The digital equivalent of the set point value (degrees or millivolts) is then found by subtracting the lowest number of the selected range from the desired set point and then dividing by the units per digit. For example, if the range indicated is 500-1000°C and the desired set point temperature is 850°C, the dial would be set to read 700 thus:

$1000 - 500 = 500$ degree span

$\frac{500}{1000} = .5$ degrees per digit

$\frac{850 - 500}{.5} = 700$ dial setting

If the instrument is calibrated in temperature, the reference voltage source output for a given set point may not be exact due to inherent non-linearity of thermocouple potentials. This is discussed in the first section under "Reference Voltage Source".

Control Adjustments

Final control adjustments should be made after the unit has been in operation 45 minutes and has obtained maximum stability. The controls are accessible by removing the front access cover, which is easily removed by pulling the small knob located below the control set point knob.

Proportional Band Adjustment:

The proportional band (PB) adjustment is used to vary the proportional band from 2.2% to 17% of full scale. Turning the PB adjustment clockwise will increase the PB, and counterclockwise will decrease it. The ideal PB setting is at its furthest counterclockwise or minimum adjustment which will permit straight line control. This setting is best obtained in the following manner:

1. Set the PB adjustment fully clockwise (maximum PB) and apply power to the controlled load.

2. When the controlled load temperature has become thermally stable at a point near the red arrows, reduce the PB by turning the adjustment counterclockwise one graduation on the dial. To simulate a control upset, also move the digital set point a few divisions. Allow time for the process to reach the new control point setting and then observe if there is a cyclic variation. This would appear as an up and downscale movement of the indicator pointer.

3. If cycling is not present, repeat Step 2 until cycling occurs.

4. From the setting where cycling is continuous, increase the PB by turning clockwise one graduation. Again change control set point and allow time for load temperature to stabilize. At this point, cycling should have disappeared and straight line control established.

With proportional band properly set, response time of the instrument (sensitivity to load changes) is optimized, and the control offset is also reduced.

Reset

Two reset adjustments, providing a means of aligning the meter indicator with the red arrows to correct for offset, are located on the left front of the plug-in control chassis. The coarse adjustment is to the left of the pilot bulb and the fine adjustment to the right of the bulb. The coarse reset adjustment is capable of resetting through the entire output range of the instrument's proportional band, while the fine reset adjustment can reset over just a portion of the proportional band. Using the fine adjustment, very close alignment can be obtained.

If the meter indicator does not coincide with the red arrows after the controlled load has become thermally stable, an adjustment should be made. With a small screwdriver, turn the fine reset adjustment to the midpoint of its range. Turning the reset adjustments CCW will shift the meter indicator to the left. An adjustment is then made using the coarse reset adjustment, turning it in small increments with sufficient time allowed after each adjustment to permit the controlled load to become thermally stable. When the indicator is in the close proximity of the red arrows the fine reset adjustment is utilized in the same manner as the coarse reset adjustment. The proper reset adjustment occurs when the meter indicator coincides with the red arrows when the load is thermally stable.

Maintenance and Service Checks

The 357A instrument is well designed and manufactured of high grade components and with normal care will give uninterrupted service for a long time. It is good practice, however, to have information as to service and spare parts for emergency servicing. Where a number of instruments are located together, the plug-in parts are interchangeable to allow minimum inventory.

When trouble is encountered, the service man should familiarize himself with the process and instrument application to determine the exact function of the instrument as applied. The instrument trouble usually can be traced to two basic problems: measurement or control.

Measurement trouble can be detected by observing the pointer position. If the measurement is known to be in error, check the following:

1. Open or broken thermocouple, extension wire or connector.

2. Deteriorated thermocouple. Compare readings with a test thermocouple, or measure the thermocouple output using a potentiometer. The thermocouple input test terminals are located to the left just inside the access cover of the instrument.

3. Check to see that the capacitor is properly connected between the thermocouple input terminal and the ground terminal inside the back panel of the meter-chassis unit. Also ascertain that the instrument is properly grounded.

4. Accidental shorts, grounds, or moisture in the extension wire (especially with asbestos type insulation).

5. High resistance in leads due to loose connectors, poor splicing, dirty switch contacts, and other faulty connectors.

6. Problems caused by vibration or shock.

7. Errors due to oil or grease. Do not oil or grease any part of the instrument.

8. Incorrect alignment adjustment. The correctness of this setting should be checked following any meter servicing.

9. Improper thermocouple circuit resistance. See page 21.

Control trouble may be detected by observing indicator pointer position with respect to the red arrows. If control action does not occur at the red arrows, do the following:

1. Check electrical connectors and correctness of line voltage. Ascertain as to whether trouble is internal or external to the instrument.

2. Determine if instrument, magnetic amplifier or power controller are powered; check load power for open circuits and open legs in three-phase circuits.

3. Check the supply voltage to the components. It should be within ± 10% of rated line voltage. Excessive line voltage variations can cause large fluctuations in load power.

4. Check to see if the reactor rating is compatible with the load rating.

5. Check the output of the Model 357A by connecting a d-c voltmeter to the instrument's test terminals to measure the instrument's output. When the black indicator is well to the left of the red arrows, the meter reading should be greater than 18 volts d-c. When the black indicator is to the right of the red arrows, the test meter should read 3 volts d-c or less.

6. If the instrument output is low (less than 18 volts d-c) when the indicator is considerably to the left of the red arrows, check for improper reset adjustment.

7. If there is no power applied to the load with the instrument energized, attach a d-c voltmeter to the test jacks. If the voltmeter indicates zero output, make sure the meter indicator is well to the left of the red arrows and then turn the reset adjustment through its entire adjusting range. If the d-c voltmeter then indicates an output to the controller, let the controlled load stabilize and then make an adjustment of reset as described under "Control Adjustments". If the instrument does not then function, further servicing or replacement of the control chassis is suggested.

8. If cycling is present at maximum proportional band, see section on "Proportional Control".

Item	Part No.	Description
C1	39-163	100 mfd + 80% -20% 50 v d-c w
C2	39-098	1 mfd 200 v d-c
D1	37-030	Silicon Diode 60 piv 50 ma
D2	31-046	18 v ± 20% 1 watt Zener Diode
D3	31-027-100	9 - 9.8 v at 10 ma Temp. C. ± .005%/°C
D4	37-030	Silicon Diode 60 piv 50 ma
D5	37-030	Silicon Diode 60 piv 50 ma
D6	37-030	Silicon Diode 60 piv 50 ma
R1	40-233	270 ohms ± 10% 1 watt Compensator
R2	40-160	530 ohms ± 1% 2.5 watt w.w.
R3	40-162	10 k ohms ± 1% 1 watt w.w.
R4	40-161	232 ohms ± 1% 2.5 watt w.w.
R5	40-180	1 k ohms ± 1% 3 watt w.w.
R6 thru R10	A-4409-100	Calibrating Resistors (See Eng. Specs.)
R11	29-137	0-1000 ohms ± 3% 1.5 watts 10 turn pot
R12	A-4409-100	Calibrating Resistors (See Eng. Specs.)
R14	BYZR 83-4	500 ohm Potentiometer
R15	CYZR 170-14	680 k ± 10% 1/2 watt
R16	A-4409-100	13 ohm ± .1 Resistor
R_{cj}	See Table #1	
S1	32-258	3P-3T Rotary Switch

TABLE #1

TC Type	R_{cj}
Type J	A-3476
Type K	A-3477
Type T	A-3478
Type E	A-3479
Types R and S	A-3480

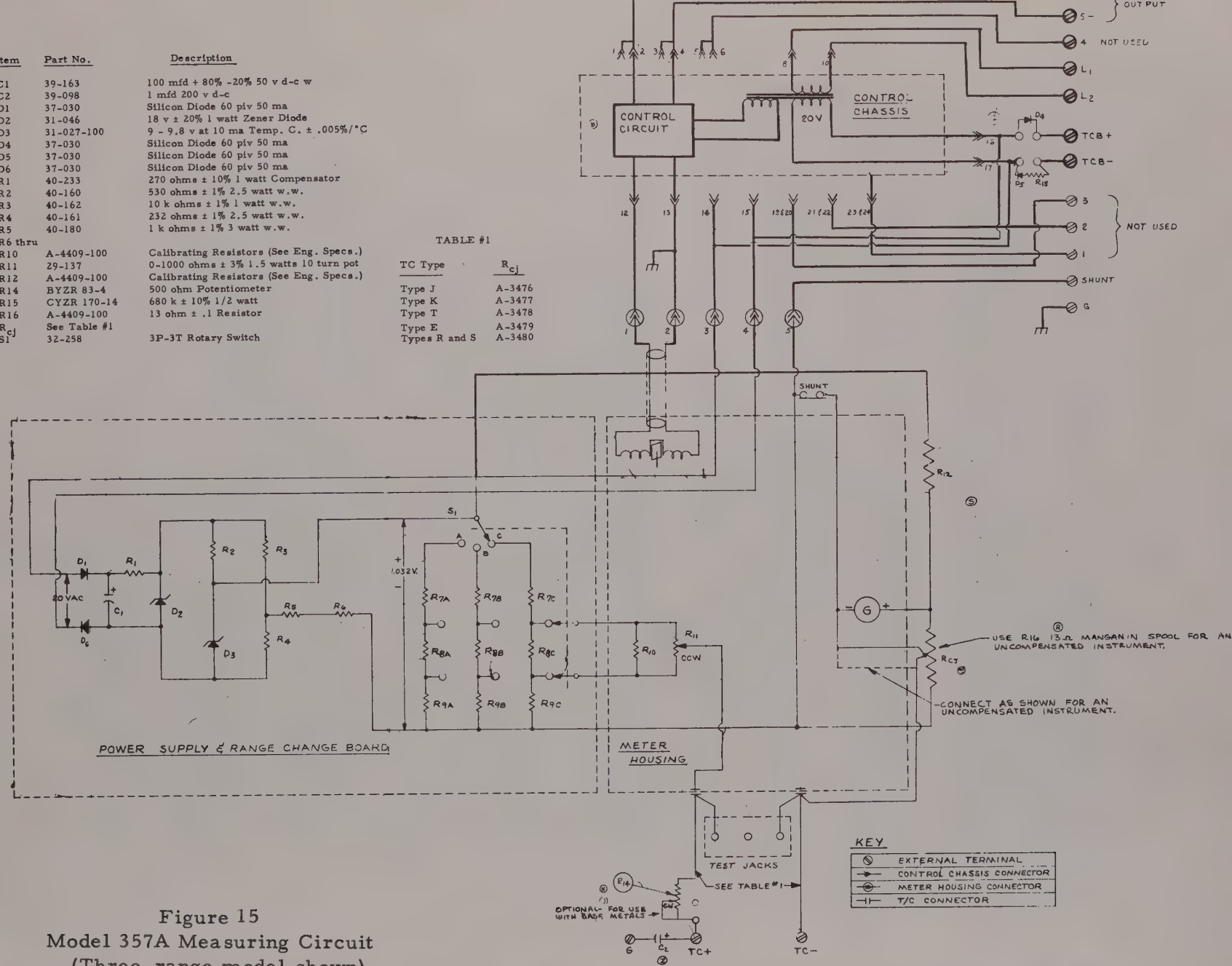
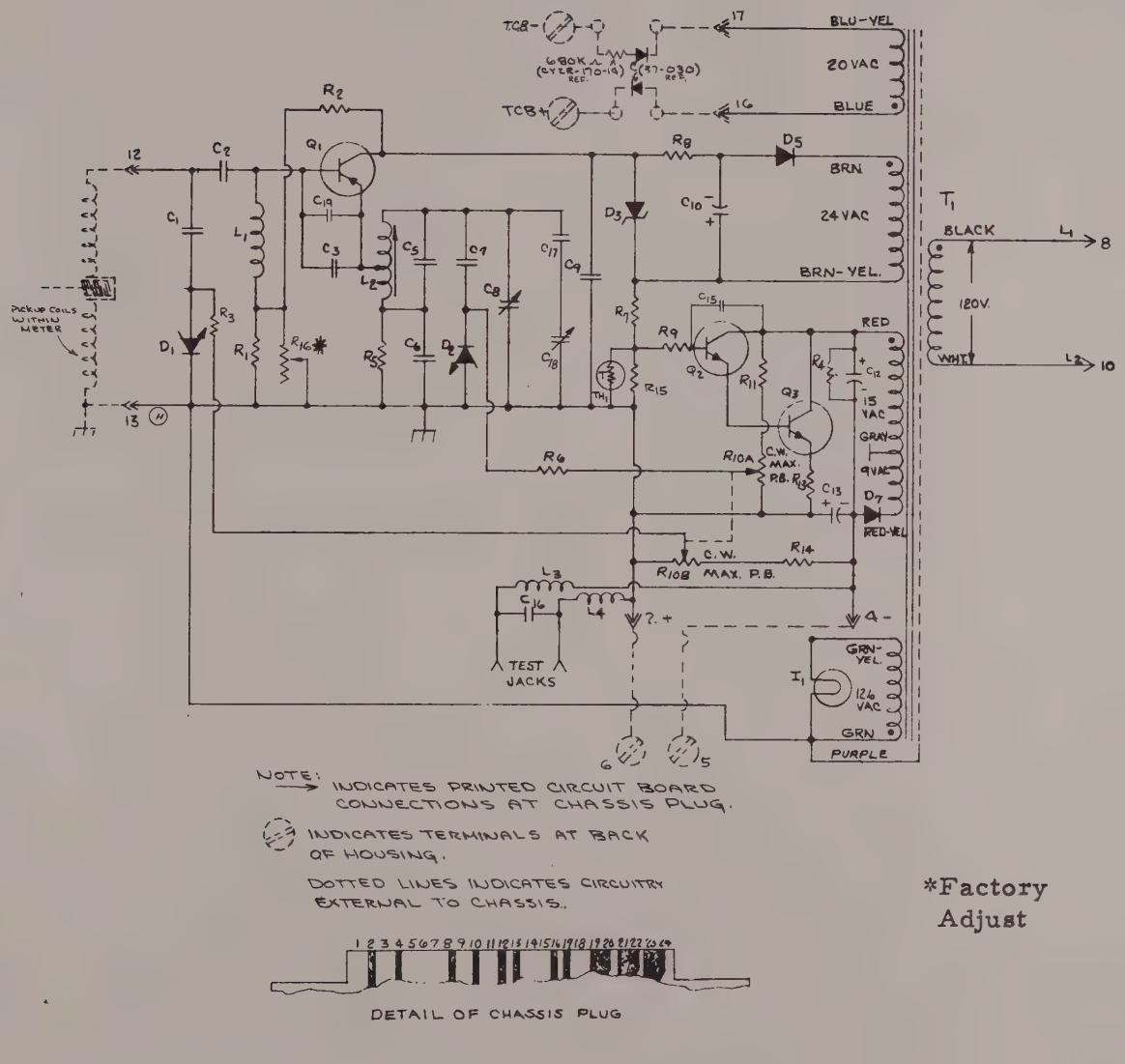


Figure 15
Model 357A Measuring Circuit
(Three-range model shown)



*Factory Adjust

Figure 16

Model 357A Control Circuit Schematic

PARTS LIST

For Parts Shown in Figure 16

Item	Part No.	Description
C1, C7	39-69	100 pfd 600 v d-c w ± 5% NPO
C2, C6	39-76	250 pfd 500 v d-c w ± 20% NPO
C3	39-212	8 pfd 500 v d-c w ± 10% N4700
C5	39-80	47 pfd ± 10% 600 v d-c w NPO
C8, C18	39-160-1	2.9-35 pf
C9, C16	39-103	.01 mfd 1000 v d-c w ± 10%
C10, C13	39-153	50 mfd 50 v d-c w -10 +150%
C12	39-163	100 mfd 50 v d-c w -20 +80%
C15	39-228	.47 mfd 50 v d-c w ± 10%
C17	39-89	5 pfd 500 v d-c w N150
C19	39-155	10 pfd 600 v d-c w ± 5%
D1, D2	37-60	Variable Capacitor 33 pf at 4 volts
D3	37-93	12 volt Zener Diode 400 mw ± 10%
D5, D7	EYZP 384	Silicon Diode 80 piv at 100 ma
I1	36-34	12.6 volt Bulb
L1	41-133	22 μH ± 10% Coil
L2	41-130	2.7 μH Coil
L3, L4	41-124	60 μH 10% Choke Coil
Q1	31-50	High Frequency Transistor (2N2188)
Q2, Q3	31-69	600 mw Silicon Transistor (2N696)
R1	CYZR 133-2	1500 ohm ± 10% 1/2 watt
R2	40-82	33 k ohm ± 10% 1/2 watt
R3, R6	CYZR 170-18	4700 k ohm ± 10% 1/2 watt
R4	CYZR 170-58	10 k ohm ± 10% 1/2 watt
R5	40-77	270 ohm ± 10% 1/2 watt
R7	CYZR 170-47	330 ohm ± 10% 1/2 watt
R8	CYZR 133-2	1500 ohm ± 10% 1/2 watt
R9	CYZR 105	8200 ohm ± 10% 1/2 watt
R10A and R10B	29-148	100 k ohm ± 10% 1/2 watt dual unit Pot
R11, R14	40-70-2	47 k ohm ± 10% 1/2 watt
R13	40-78	15 ohm ± 5% 1/2 watt
R15	CYZR 170-36	680 ohm ± 10%
R16	BYZR 147-1	15 k ohm 1/4 watt Pot
T1	30-144	Power Transformer
TH1	CYZR 676	Thermistor

SUGGESTED REPLACEMENT PARTS TO KEEP ON HAND

Quantity	Part Number
2 MAZDA Pilot Lamps	36-34
1 Replacement Thermocouple	Barber-Colman can supply thermocouple assemblies, components or wire for any requirement you may have. If need be, delivery will be made in 48 hours. Contact your nearest Barber-Colman field office.
1 Indicating Meter Assembly	Specify range and calibration.
1 Control Chassis	A-5988

We do not recommend electronic component replacement except by well equipped instrument repair shops.

Barber-Colman, Industrial Instruments Division, maintains service and repair facilities in many major cities in the United States and Canada. Consult your yellow page directory.

MATERIAL WARRANTY

All equipment except tubes, photocells, and thermocouples, which within one year from date of shipment is found to have been originally defective, will be repaired (replaced if necessary) free of charge, if returned immediately, prepaid, to the Factory at Rockford, Illinois.

STANDARD RANGES AND THERMOCOUPLE ERRORS

On the following pages is a list of standard Digiset ranges, also showing the error to be expected for each temperature range due to thermocouple non-linearity. See Figure 1. The selection of range for a particular application must consider the measurement error acceptable. When close accuracy is required, it is recommended that a unit calibrated in millivolts with cold junction compensation be specified. The error due to thermocouple non-linearity would thus be eliminated.

The table below shows additional errors due to the standard limits of error of the thermocouple material. These errors, plus thermocouple non-linearity and instrument calibration errors, are additive (algebraically) for determining total maximum error possible for a given dial setting.

Calibration	Temperature Range	Standard Limits of Error
THERMOCOUPLE WIRE		
	-300 to - 75°F	- - -
Copper-Constantan	-150 to - 75°F	± 2%
Type T	- 75 to +200°F	± 1 1/2°F
	200 to 700°F	± 3/4%
Iron-Constantan	32 to 530°F	± 4°F
Type J	530 to 1400°F	± 3/4%
Chromel-Alumel	32 to 530°F	± 4°F
Type K	530 to 2300°F	± 3/4%
Platinum-Rhodium-Platinum	32 to 1000°F	± 5°F
Type R or S	1000 to 2700°F	± 0.5%

From I.S.A. Recommended Practice R.P. 1.3.

THERMOCOUPLE EXTENSION WIRE		
Copper-Constantan Type T	- 75 to 200°F	± 1 1/2°F
Iron-Constantan Type J	0 to 400°F	± 4°F
Chromel-Alumel Type K	0 to 400°F	± 4°F
Alternate Extension Wire Copper-Copper Alloy for use with Types R and S	75 to 400°F	± 12°F

NOTE: Percent limits of error shown are a percent of actual temperature indicated.

DIGISET STANDARD RANGES AND NON-LINEARITY ERRORS

NOTE:

(1) Ranges are listed in ascending order by top of range.

(2) Errors due to non-linearity of the thermocouple are figured at the midpoint of the temperature range. On either side of midpoint, error may be greater or less, depending on the shape of the thermocouple emf-temperature curves. See page 2.

Plus sign in front of the error figure designates the amount that actual temperature is above set point value. Minus sign designates actual temperature below set point.

IRON-CONSTANTAN
Type J

Code Number	Ranges	Thermocouple Non-Linearity
306	0- 500 F	+3.5°
17	0-1000 F	+3.5°
2291	100- 600 F	+1.5°
	500-1000 F	+ .5°
2292	100- 600 F	+1.5°
	500-1000 F	+ .5
	900-1400 F	+5.0°
23	0- 500 C	+1.5°

CHROMEL-ALUMEL
Type K

207	0-1000 F	+5.0°
2293	100-1100 F	+5.0°
	1000-2000 F	-7.5°
2296	100-1100 F	+5.0°
	1000-2000 F	-7.5°
	1900-2900 F	-5.0°
	(error for midpoint of 1900-2500 range)	
33	0-1000 C	0.0°
2295	100- 600 C	+4.0°
	500-1000 C	-3.0°
	900-1400 C	-5.5°

CHROMEL-ALUMEL (cont'd)
Type K

Code Number	Ranges	Thermocouple Non-Linearity
2297	0-30 mv	
1373	0-50 mv	
1371	35-45 mv	
	43-53 mv	
2294	27-37 mv	
	36-46 mv	
	45-55 mv	
2324	0-20 mv	
	19-39 mv	
	38-58 mv	

COPPER-CONSTANTAN
Type T

2309	-100 to + 400 F	+15.5°

13% PLATINUM-RHODIUM
Type R

2302	100-1100 F	+28.0°
	1000-2000 F	+13.5°
	1900-2900 F	+ .5°
276	0-1000 C	+35.4°
1408	800-1300 C	+ 4.5°

13% PLATINUM-RHODIUM (cont'd)
Type R

Code Number	Ranges	Thermocouple Non-Linearity
2093	100- 600 C	+11.0°
	500-1000 C	+ 6.0°
	900-1400 C	+ 2.5°
1625	500-1000 C	+ 6.0°
	900-1400 C	+ 2.5°
1421	5-15 mv	
2299	0-10 mv	
	9-19 mv	
2301	0-10 mv	
	9-19 mv	
	18-28 mv	

10% PLATINUM-RHODIUM
Type S

2308	100-1100 F	+22.5°
	1000-2000 F	+11.0°
	1900-2900 F	0.0
106	0-1000 C	+28.3°
2304	800-1300 C	+ 3.5°
2307	100- 600 C	+ 8.0°
	500-1000 C	+ 5.0°
	900-1400 C	+ 2.0°
2305	0-10 mv	
	9-19 mv	
2306	0-10 mv	
	9-19 mv	
	18-28 mv	
1538	5-15 mv	

PLATINEL II
(Alloys 1813 and 1503)

Code Number	Ranges	Thermocouple Non-Linearity
2316	100-1100 F	+18.9°
	1000-2000 F	-13.5°
	1900-2900 F	-26.2°
	(midpoint error for range 1900-2732)	
2310	0-1000 C	+ 7.0°
1856	800-1300 C	- 8.6°
2315	100- 600 C	+ 6.0°
	500-1000 C	- 4.8°
	900-1400 C	-11.1°
2313	0-10 mv	
	9-19 mv	
	18-28 mv	
2312	35-45 mv	
	43-53 mv	
2314	27-37 mv	
	36-46 mv	
	45-55 mv	
2325	0-20 mv	
	19-39 mv	
	38-58 mv	

MV RANGES - UNCOMPENSATED

1438	0-10 mv
2320	0-10 mv
	9-19 mv
	18-28 mv
2317	0-30 mv
2318	0-50 mv
2321	0-10 mv
	0-25 mv
	0-50 mv
2319	0-25 mv
	0-50 mv

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